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**Physiotherapy intervention for 4-5 year old children born extremely
preterm and/or extremely low birth weight.**

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Abstract

Neurodevelopmental impairments amongst the extremely low birth weight (ELBW) or extremely preterm population are well recognised. However, support services for these children who have mild impairments are lacking. This research aimed to explore the performance of a group of non-disabled ELBW or extremely preterm children with minimal/mild impairments over a 12 month period at a critical time-point, coinciding with the commencement of formal education. Performance of these children was established, as well as whether impairments persist. Persistence of impairments may suggest a widening gap between performance of these children and expected performance of term born peers. Additionally, this research aimed to investigate the short term and longer term impact of group-based physiotherapy intervention compared to standard care.

Subjects

Fifty children born ELBW and/or extremely preterm (26 males; mean birth weight: 838.8g, SD 174.8g; mean gestational age: 27.0 weeks, SD 2.0 weeks) with minimal/mild motor impairments and a mean age (corrected for prematurity) of 50 months (SD 2.6 months) at baseline. Twenty-four children were randomised to intervention and 26 children to standard care.

Methods

Children were assessed by paediatric physiotherapists blinded to group allocation. A set testing protocol was used. Baseline assessment included: Movement Assessment Battery for Children second-edition (MABC-2), tests of postural stability and limb strength, Child Behavior Checklist (CBCL) and Beery Visual-Motor Integration Test 5th Edition (Beery VMI). Following baseline assessment, children were randomly allocated to intervention or standard care. All children were assessed on motor and postural tests at the conclusion of the intervention. Goal Attainment Scaling (GAS) was utilised within the intervention group. At one year post baseline assessment, all children were assessed on baseline tests, as well as Peabody Picture Vocabulary Test 4th Edition (PPVT-4).

Results

Study I: Motor performance, postural stability and behaviour of non-disabled extremely preterm or extremely low birth weight children at four to five years of age

The group had low average motor co-ordination, lower than expected postural stability and strength, and acceptable behaviour. Mean percentile rank on MABC-2 was 31%. However, 30% of children had a score less than or equal to the 15th percentile, indicating at risk of or having a definite motor problem and these children had poorer postural outcomes compared to children with normal motor performance. Behaviour was within normal range according to performance on CBCL, although between 11-15% of children had a score within the clinical range. Behaviour of males was poorer than that of females.

Study II: Group-based physiotherapy intervention to improve motor co-ordination, postural stability and limb strength in non-disabled ELBW children: a randomised controlled trial

Both intervention and standard care led to improvements in motor co-ordination, postural stability and strength of the children. There were no between group differences over time. Within group comparison demonstrated that both groups improved on all measures, although the intervention group made significant improvements on more postural control measures.

Study III: A randomised controlled trial of group-based physiotherapy intervention for non-disabled ELBW children: one year follow-up of motor and postural outcomes

Motor performance of the whole group declined from baseline to one year follow-up (except MABC-2 balance scores), but postural stability and strength improved. Motor performance remained at the lower end of the normal range. There was no group by time interaction on any measures.

Study IV: GAS to explore effect of group-based physiotherapy intervention on personal growth of non-disabled ELBW children

Intervention was effective with GAS mean T score of the group exceeding the expected level (mean=58.17, SD=0.82). Goal attainment was associated with motor co-ordination

and children with better motor skills post intervention, were more successful in reaching goals. Females improved more than males on GAS.

Study V: Behaviour of 4-5 year old non-disabled ELBW children: outcomes following group-based physiotherapy intervention

The total study group had a mean performance within normal range at four and five years of age. At one year follow-up, 9% of children had a CBCL score within the clinical range. Both intervention and standard care had a positive effect on behaviour. Behaviour of males was poorer than that of females at follow-up. Behaviour was not related to performance in other neurodevelopmental domains.

Conclusions

The group of non-disabled extremely preterm or ELBW children performed, on the whole, within normal range at four to five years, and at a higher level than expected. Group-based physiotherapy intervention and adherence to best practice advice yielded positive motor and postural outcomes in the short term and had longer term postural benefits. Both approaches had a positive effect on behaviour. Intervention also facilitated personal growth through goal attainment. However, the longer term impact of intervention was no different to best practice advice. Neither approach was sufficient to ameliorate against the ongoing nature of motor problems, and it is likely that as these children progress through school and are confronted with increasing challenges, problems across multiple domains will become more apparent.

Declaration by author

This thesis is composed of my original work, and contains no material previously published or written by another person except where due reference has been made in the text. I have clearly stated the contribution by others to jointly-authored works that I have included in my thesis.

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Contributions by others to the thesis

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List of Abbreviations

ADHD	Attention deficit hyperactivity disorder
BOTMP	Bruininks-Oseretsky Test of Motor Proficiency
CI	Confidence interval
CP	Cerebral palsy
CBCL	Child Behavior Checklist
DCD	Developmental co-ordination disorder
DSM-V	Diagnostic and Statistical Manual of Mental Disorders 5 th Edition
ELBW	Extremely low birth weight
GAS	Goal Attainment Scaling
IBAIP	Infant Behavioural Assessment and Intervention Program
ICF	International Classification of Functioning, Disability and Health
IQR	Inter-quartile range
IQ	Intelligence Quotient
LBW	Low birth weight
MABC	Movement Assessment Battery for Children
MMRC	Mater Mothers' Research Centre
MRI	Magnetic Resonance Imaging
NIDCAP	Newborn Individualised Developmental Care and Assessment Program
NSMDA	Neuro-sensory and Motor Developmental Assessment
PPVT-4	Peabody Picture Vocabulary Test-4 th Edition
PRT	Paediatric reach test
RCT	Randomised controlled trial
RDS	Respiratory distress syndrome
SD	Standard deviation
SE	Standard error
SLS	Single leg stance
SS	Standard score
VLBW	Very low birth weight
VMI	Visual-motor integration

CHAPTER 1

INTRODUCTION: OVERVIEW OF NEURODEVELOPMENT AND CHILDREN BORN EXTREMELY PRETERM / ELBW

Children born extremely preterm or extremely low birth weight (ELBW) often present with a range of impairments that adversely affect the early years of their development (Burns et al., 2004; Burns et al., 2009; Goyen & Lui, 2002, 2009; Hutchinson et al., 2013; Woodward et al., 2009). In order to study the type and extent of these difficulties and the role of intervention, it is important to understand the context of development and the classification of health and health-related domains according to the International Classification of Functioning, Disability and Health (ICF) (World Health Organization, 2001). With this background in mind, this chapter will describe the extremely preterm/ELBW population in detail, as well as factors relevant to development of these children and why these children are vulnerable to impairments. Additionally, intervention and its application to the extremely preterm/ELBW population will be addressed.

1.1 Dynamic systems theory of development and its relationship to the ICF

Development is a complex process that is influenced by multiple interacting systems and environments (Sweeney et al., 2010). In the dynamic systems theory of development (Thelen & Smith, 1994), system components include biological elements, socio-cultural and environmental influences, in addition to task related factors (Sweeney et al., 2010). The dynamic systems concept incorporates the synactive theory of development (Als, 1982) and the theory of neuronal group selection (Edelman, 1987). The synactive theory is based on a behavioural organisation process of five subsystems (autonomic, motor, state-organisational, attentional-interactive, and self-regulatory) that are thought to be interdependent and interact in an ongoing cycle that is affected by the environment (Als, 1982). Physiologic stability is fundamental to the functioning of these subsystems and the theory of neuronal group selection is framed around biological and observational concepts. In this theory, the brain functions as a selective system and is influenced by the body and the environment either as the fetus develops in utero or after birth: the brain

undergoes organisation and reorganisation as a result of neural plasticity (Edelman, 2006). Therefore, the behavioural and neuronal foundations that underpin the synactive theory of development and the theory of neuronal group selection, are key elements of the dynamic systems model.

The dynamic systems approach to development aligns well with the ICF model, which represents a framework for classifying health and disability both at an individual level and at a population level (World Health Organization, 2001). At the individual level, the ICF framework signifies the relationship between health (body functions and structures, activities and participation) and the contextual factors associated with the environment and person (Sweeney et al., 2010; World Health Organization, 2001).

1.2 Application to the preterm infant

In the context of preterm birth, natural developmental processes are often adversely affected (van Baar et al., 2005). Employing the ICF model, preterm birth can result in domain based dysfunction that incorporates impairments eg. motor and behaviour (Hutchinson et al., 2013; Williams et al., 2010), activity limitations eg. functional limitations (Grunewaldt et al., 2014) and participation restrictions eg. quality of life implications (Theunissen et al., 2001; Vieira & Linhares, 2011) for these members of society. Subsequently, preterm birth can be associated with disability as those affected have a health condition where weaknesses in one or more domains interact with personal and environmental factors (World Health Organization, 2014). Disabilities amongst children who were born very and extremely preterm (see description in 1.3 below) commonly involve multiple neurodevelopmental domains, such as motor, cognitive functioning, language and behaviour, and these impairments are often inter-related (Arpi & Ferrari, 2013; van Baar et al., 2005; Woodward et al., 2009). It has been reported that nearly 50% of eight year old children born extremely preterm or ELBW have mild to severe disabilities in multiple domains (Hutchinson et al., 2013). For these children, the consequences of numerous comorbid neurodevelopmental problems are far greater than if very preterm children had a disability in a single domain (Woodward et al., 2009).

As development progresses, these impairments and activity limitations are likely to have a cascading effect for very preterm children, and long term consequences. There is a potential financial burden on society with further support services required for very preterm individuals, for instance, in the educational system, due to increased learning needs and to optimise the participation of these children in society (Bhutta et al., 2002; Mâsse et al., 2013; Theunissen et al., 2001; Vieira & Linhares, 2011). It has been highlighted in the literature that children with neurodevelopmental problems have reduced participation levels at school, especially in relation to motor and social impairments when it comes to physical activity (Mâsse et al., 2013).

Survival rates amongst extremely preterm or ELBW infants have improved over time with technological advancements in neonatal intensive care, but it has been reported that since the late 1990s survival rates have plateaued and there remains a need for further improvement in the neurodevelopmental outcomes of these children (Doyle et al., 2011; Hutchinson et al., 2013). In 2010, more than one in 10 babies born worldwide were born prematurely, which equates to approximately 15 million preterm births (Blencowe et al., 2012). However, although it appears that major disabilities amongst this population have stayed fairly constant over the past decade, the incidence of milder problems appears to be rising (Saigal & Doyle, 2008). It has been reported that up to 50% of very low birth weight (VLBW) children can present with problems of motor co-ordination, postural stability, attention and fitness from the age of three and four years, through school age and adolescence, and even into adulthood (Bos & Roze, 2011; Bracewell & Marlow, 2002; Burns et al., 2004; Burns et al., 2009; Danks, 2010; Goyen & Lui, 2009; Grunewaldt et al., 2014; Hack et al., 2002; Keller et al., 1998; Powls et al., 1995; Shumway-Cook et al., 2003; Spittle et al., 2009). For the purpose of this thesis, the emphasis will be on the following neurodevelopmental domains: motor, postural stability, and behaviour, cognitive function and attention. These domains will be further explored within the context of the extremely preterm or ELBW population who are non-disabled. In other words, these children escaped significant disability and are otherwise able bodied. The outcomes for this group of children appear to have been overlooked until more recent times and therefore this issue requires particular attention.

1.3 Defining the extremely preterm and ELBW population

In defining the target population, both prematurity and birth weight are factors to be considered. In terms of prematurity, according to the World Health Organization (WHO), preterm refers to less than or equal to 37 weeks of completed gestation and is divided into three categories: late (or moderately) preterm, very preterm, and extremely preterm (World Health Organization, 2014). Late preterm refers to infants born between 32 and 37 weeks gestational age. Very preterm includes those infants born between 28 to less than 32 weeks gestational age. Finally, extremely preterm infants are those born at less than 28 weeks gestational age. Prematurity has been identified as the leading cause of neonatal death in the first month of life and is the second largest direct cause of death in children less than five years of age (Liu et al., 2012). Prevalence of cerebral palsy has been reported to be 14.6% for children born extremely preterm, 6.2% for very preterm children, 0.7% for late preterm children and 0.1% for term age children (Himpens et al., 2008). More recently, cerebral palsy amongst children born between 22 to 25 weeks gestational age has been reported to be between 9% to 18% with the rate of severe neurodevelopmental disabilities 17% to 59% (Jarjour, 2015). In relation to low birth weight (LBW; infants born with a birth weight less than 2,500g), this can be further classified as VLBW, referring to those born less than 1,500g, and ELBW, infants born less than 1,000g (Saigal & Doyle, 2008). It is relevant here to define “small for gestational age” as this is a risk factor for perinatal morbidity and mortality as well (Carberry et al., 2014). Small for gestational age usually refers to those infants who have a weight and length below the 10th centile for gestational age (World Health Organization, 2016). However, extremely preterm and/or ELBW children are the target population of this thesis rather than children with a history of small for gestational age.

In defining the preterm population it is necessary to raise the issue of corrected age. During infancy and childhood, preterm infants are often referred to in terms of their corrected age, which refers to the age of the infant from the expected date of delivery (Committee on Fetus and Newborn, 2004). It is important to use corrected age in this population as it mitigates the potentially confounding influences of biological maturity on abilities and ensures accurate evaluation of performance (DiPietro & Allen, 1991). Therefore, the overall development and attainment of milestones of preterm infants follows a trajectory more comparable to the infants’ gestational age rather than chronological age

or time elapsed from birth (Committee on Fetus and Newborn, 2004; DiPietro & Allen, 1991). In terms of timeframes for when to discontinue using corrected age for preterm infants, there is a significant degree of variability in the literature (DiPietro & Allen, 1991). However, generally, the lower the gestational age of the child (the length of time between the first day of the last menstrual period and the day of delivery) (Committee on Fetus and Newborn, 2004), the longer the time for which corrected age should be used. In the case of a child with a history of extreme prematurity, it is reasonable to continue using corrected age until the child is five years of age or until formal school education has commenced (chronological age is used in the school system) (DiPietro & Allen, 1991). The children included in the studies that follow were part of a hospital based follow-up program. The policy of this program is to continue correcting age until the child is four years of age, therefore, corrected age was used throughout this thesis.

1.4 Summary of contributing factors to neurodevelopmental impairments & the role of surveillance

Despite using corrected age amongst the extremely preterm population, as previously stated, the prevalence of mild neurodevelopmental problems is increasing (Hutchinson et al., 2013; Saigal & Doyle, 2008). In terms of the aetiology driving the emergence of these impairments, although several theories have been proposed, there appears to be a lack of consensus in the literature. Biological factors have been suggested to play a part, including birth weight (Sullivan & Msall, 2007; Vieira & Linhares, 2011), gestational age (Anderson et al., 2004), perinatal illness (Dammann, 2001; Potharst et al., 2013) and gender (Marlow et al., 2005). Environmental factors have also been reported to influence prognosis in this population, including socio-economic status (Ornstein et al., 1991), parent-child relationship (Sajaniemi et al., 2001) and maternal characteristics (Hack et al., 1995). However, the relationship between biological and environmental factors and neurodevelopmental outcomes in LBW children has been challenged in the literature (Sommerfelt, Troland, et al., 1996). For example, behavioural problems amongst LBW children have been reported to have no association with birth weight, gestational age, perinatal and postnatal factors or parental risk factors (Sommerfelt, Troland, et al., 1996).

Neurodevelopmental problems amongst extremely preterm or ELBW children can be predicted and identified in the first few years of life (Arpi & Ferrari, 2013; Danks et al., 2012; Goyen & Lui, 2009; Woodward et al., 2009). Although there are inconsistencies in the literature in relation to the influence of biological and environmental factors on neurodevelopmental outcomes in this population, there is evidence that surveillance, commencing from infancy and continuing into school age (particularly in the form of motor assessment), is predictive of later performance in 'apparently normal' extremely preterm or ELBW children (Danks et al., 2012; Goyen & Lui, 2009). This finding is significant as it highlights the importance of developmental follow-up services for these children to ensure a proactive, as opposed to a re-active, approach to management is adopted. Early recognition of neurodevelopmental problems amongst non-disabled ELBW children means that parents can be alerted about the potential difficulties that their child may experience and ensures that the child can be prioritised for early intervention (Goyen & Lui, 2009).

1.5 Interventions

Developmental intervention programs for the preterm population have been established for many years. However, most of these have used a variety of interventions and assessments targeted at young infants and their effectiveness has mainly been limited to short-term gains (Orton et al., 2009; Spittle et al., 2015). Currently, there are minimal, if any, support services available for non-disabled children born extremely preterm with mild neurodevelopmental impairments. Therefore, it is essential to explore the potential benefits of intervention for these children; in particular, intervention that is tailored to the individual and intervention that will have positive long term effects. This will assist in managing the ongoing impact of preterm problems and the potential impact these problems may have on quality of life (Theunissen et al., 2001; Vieira & Linhares, 2011).

Intervention for extremely preterm or ELBW children at four years of age is of particular importance. Adequate preparation for school is fundamental as it is often felt that these children lack school readiness and this concern is shared by both teachers and parents (Roberts et al., 2011). Intervention may assist in preparing these children to cope with the demands of the classroom when they commence formal school education, and in turn, may diminish the risk of school failure and the problems that could follow. Additionally,

strong links have been found between performance of preterm born children at four years of age and performance in early teenage years (Danks et al., 2012; Hansen et al., 2002; Sullivan & McGrath, 2003; Sullivan & Msall, 2007). Therefore, the predictive value of performance at four years means that those likely to have ongoing difficulties can be identified and further highlights that improvements at this age may have more positive long term effects, which may be strengthened by the potential transitional nature of development at this age (Shumway-Cook & Woollacott, 1985).

A search of the literature did not reveal any studies that have investigated the effect of group-based intervention for four year old children born extremely preterm or with ELBW who have mild neurodevelopmental impairments. If these impairments can be alleviated, then this has the potential to minimise activity limitations and promote participation for these individuals, which emulates the ICF model. There is a need for additional research in this area, including further intervention studies at school age for high-risk preterm born children and this has been recommended in the literature (Doyle et al., 2014).

1.6 Purpose of thesis

The purpose of this thesis was to investigate the effect of a physiotherapy intervention program with four year old children born extremely preterm or with ELBW on their motor co-ordination, postural stability and behaviour compared to standard care. The specific aims were:

- To explore the short term motor and postural benefits of a specifically developed six week, small group physiotherapy intervention program compared to best practice advice for these children aged four to four and a half years (age corrected for prematurity).
- To compare motor performance, posture and behaviour between the children who received intervention with those who received advice only at 12 months post baseline assessment.
- To evaluate the impact of intervention on individualised functional change amongst intervention children.

The thesis aims were addressed through a series of five hypotheses and associated studies.

1.7 Null Hypotheses

The null hypotheses for this thesis were:

- I Non-disabled extremely preterm or ELBW children would perform no differently to their term born peers at four years of age.
- II The short term effects of group-based physiotherapy intervention on motor co-ordination, postural stability and limb strength would be no different to standard care in non-disabled ELBW children.
- III Motor and postural outcomes one year post baseline in non-disabled ELBW children who underwent group-based physiotherapy intervention would be no different to those children who received standard care.
- IV Group-based physiotherapy intervention in non-disabled ELBW children would not lead to personal growth via goal attainment.
- V The behaviour of 4-5 year old non-disabled ELBW children who underwent group-based physiotherapy intervention would be no different to those children who received standard care.

CHAPTER 2

NEURODEVELOPMENTAL OUTCOMES AMONGST NON-DISABLED EXTREMELY PRETERM / ELBW CHILDREN

In order to understand the bases for the studies reported in this thesis, it is important to review current knowledge regarding the neurodevelopmental outcomes of children born preterm or LBW who are classified as non-disabled. Where possible, the focus will be specifically on the extremely preterm or ELBW contingent. Neurodevelopmental problems amongst extremely preterm or ELBW children who have no major impairments are complex, subtle and often interrelated: they can be overlooked due to the overall ability of this group of children and the minimal nature of their problems (Burns et al., 2004). However, the high prevalence of neurodevelopmental impairments in non-disabled extremely preterm born children is reported extensively in the literature, particularly in the domains of motor, postural stability, and behaviour, cognitive function and attention (Bos & Roze, 2011; Bracewell & Marlow, 2002; Burns et al., 2009; Danks, 2010; Goyen & Lui, 2009; Hack et al., 2002; Hack et al., 1995; Hutchinson et al., 2013; Keller et al., 1998; Powls et al., 1995; Saigal & Doyle, 2008). In the context of the dynamic systems theory of development, these neurodevelopmental impairments have the potential to have an adverse impact on development and life in general for these individuals (Sweeney et al., 2010).

Therefore, this chapter will explore the impact of prematurity and LBW on development, particularly the effects on movement, posture, and behaviour amongst the extremely preterm and ELBW children. These effects will be considered in alignment with the ICF framework of body function, activity and participation implications. Furthermore, the aetiology of neurodevelopmental problems amongst this population will be considered and this group of children will be compared with other cohorts of children. Finally, the role of intervention and the potential for more optimal outcomes for preterm and LBW children will be explored.

2.1 Effect of preterm birth on neurodevelopmental outcomes - motor

The following section will examine the effect of preterm birth on motor outcomes.

2.1.1 Motor performance and infancy

Mild motor problems are one of the most common 'hidden disabilities' amongst preterm or low birth weight children and are apparent from an early age (Bracewell & Marlow, 2002). The prevalence of minimal or mild motor difficulties at one year corrected age amongst a cohort of non-disabled ELBW infants has been reported to be 19.6% and 10.9% respectively (Zanudin, Burns, et al., 2013). During infancy, many preterm or low birth weight children have problems in the regulation of muscle tone, which may be secondary to an imbalance between the extensor and flexor muscles, with a predominance of hyperextension of the trunk and extensor tone of the lower limbs (Bracewell & Marlow, 2002). This motor phenomenon, also known as 'transient dystonia', has been linked to motor performance through to school age (Samsom et al., 2002; Sommerfelt, Pedersen, et al., 1996).

Early motor ability of ELBW infants has been predictive also of function in other areas. Burns et al found that group classification of motor performance at one year corrected age, was predictive of cognitive function at four years corrected age (Burns et al., 2004). In their study, even children with minimal movement problems demonstrated lowered cognitive functioning.

2.1.2 Motor performance, early childhood and gestational age

The ongoing nature of motor problems amongst children born very preterm has been examined by Janssen et al, who reported the incidence of delayed motor performance to be 46.5% at two to three years corrected age (Janssen et al., 2008). This study excluded children with severe disabilities. Furthermore, Hemgren et al, through their studies of preterm children at three years corrected age, found that very preterm children performed more poorly on motor tasks than moderately preterm and full term children. The authors also demonstrated that there was a relationship between the quality of motor performance and gestational age, with very preterm children having significantly lower quality of motor

performance than children born at higher gestational ages and those born at term age (Hemgren & Persson, 2002, 2004). These findings may relate back to differences in the regulation of muscle power and postural control amongst the preterm population or may be linked to delays in neural maturation (Hemgren & Persson, 2004). It is possible that if these studies had included an extremely preterm group, the reduced motor abilities found amongst lower gestational ages of the preterm cohort at large (not isolated to non-disabled), would have been further emphasised.

However, this concept of a link between motor outcome and gestational age has been challenged (Bos & Roze, 2011). Bos and Roze investigated the distribution of cognitive and motor scores in a sample of 6-12 year old children born very preterm and the impact of brain lesions and decreasing gestational age on these scores. The study concluded that the distribution curve for cognitive and motor outcomes was shifted to the left but did not identify an effect of brain lesions or decreasing gestational age on cognitive or motor performance. It is important to note that in this particular study all children were born at less than 32 weeks' gestational age, therefore there was no moderately preterm group as there was in the previous studies by Hemgren et al. Additionally, in the study by Bos and Roze, there was only a small number of children born at 24 and 25 weeks gestational age, which may have contributed to the lack of an effect of decreasing gestational age. Furthermore, the age of follow-up was different between the studies: perhaps the impact of gestational age is more evident at an earlier age.

2.1.3 Altered motor performance with age

Upon reaching school age and beyond, a link between prematurity or LBW and decreased motor skills has been identified, and this reduction in motor performance may adversely affect school performance (Bos & Roze, 2011; Burns & Bullock, 1985; Drillien & Drummond, 1977; Foulder-Hughes & Cooke, 2003; Keller et al., 1998; Marlow et al., 1989; Marlow et al., 1993; Williams et al., 2010). Furthermore, it has been shown that lower motor performance is more pronounced in children with a history of ELBW than those with VLBW (Keller et al., 1998). Williams et al, performed a systematic review in which they concluded that the prevalence of non cerebral palsy motor impairment amongst preterm children (born at less than 37 weeks' gestational age) at school age, is three to four times greater than that in the general population (Williams et al., 2010).

In terms of mild motor delays amongst preterm or LBW children, these appear to have a cumulative effect with age (Goyen & Lui, 2002; Sullivan & McGrath, 2003). Goyen et al investigated longitudinal motor development in a group of 'apparently normal' high-risk infants (born at less than 29 weeks' gestational age and/or less than 1,000g) (Goyen & Lui, 2002). Assessment was conducted at 18 months corrected aged, three years chronological age and five years chronological age using the Peabody Developmental Motor Scales and a home environment audit. The study concluded that gross motor deficits significantly increased over the period of investigation, particularly for children born less than 750g. Even with increasing age and maturation, the motor difficulties experienced by VLBW children do not appear to resolve (Powls et al., 1995). Despite early improvements in motor skills in a cohort of VLBW children between six and eight years of age, Powls et al found that at age 12-13 years, impairments persisted and deficits remained (Powls et al., 1995).

The enduring impact of motor difficulties on teenagers who were born extremely preterm has been further explored by Burns et al (Burns et al., 2008; Burns et al., 1999; Burns et al., 2009). Burns et al investigated whether motor co-ordination problems or poor fitness were related to learning, behaviour or self-perceptions in 11-13 year old non-disabled extremely preterm teenagers (Burns et al., 2008; Burns et al., 2009). A key finding from these studies was that the extremely preterm group performed significantly less well on tests of motor co-ordination and aerobic fitness than the term control group. Furthermore, in both groups of children, motor co-ordination rather than fitness had an increased influence on scholastic competence (reported by child and parent questionnaires) and attention. More recently, a link has been found between cardiorespiratory endurance and competence to take part in activities of daily living (reported by parent) amongst less fit ELBW children (Danks et al., 2013). This finding emphasises that fitness ability in non-disabled ELBW children may also impact on participation levels.

Additionally, in a study by Vedul-Kjelsas et al which examined the relationship between motor competence, physical fitness and self-perception in 11-12 year old mainstream primary school children (with no history of learning, behaviour, neurological or orthopaedic problems and not necessarily preterm), self-perception was shown to be closely linked to both motor competence and physical fitness (Vedul-Kjelsås et al., 2012). However,

physical fitness in males had a stronger influence on self-perception than motor competence. The overall finding of physical fitness being more closely linked to self-perception than to motor competence, may be related to the positive impact of time spent in physical activity with self-perception of fitness ability, as well as the concept of competence motivation (Chan et al., 2003; Harter, 1987). This study by Vedul-Kjelsas et al was different to the study by Burns et al on a number of levels and therefore comparison between the two studies is limited. For instance, the study by Vedul-Kjelsas et al did not use the same measures for assessing self-perception and physical fitness as the Burns et al study and there was no extremely preterm group in the Vedul-Kjelsas study.

In the study by Burns et al, the authors showed that motor co-ordination influences the fitness of ELBW and term control teenagers aged 11-13 years and that ELBW teenagers had significantly greater problems of postural stability than term controls (Burns et al., 2009). This outcome highlights the inter-relationship between motor impairments and reduced postural stability and has also been demonstrated in a study by Lorefice et al (Lorefice et al., 2012b). Furthermore, in a study examining the predictive validity of early motor scores (at 8 months, 2 years and 4 years of age) on long-term motor impairment in non-disabled ELBW children, it was found that early motor scores are valid indicators of motor performance at 11-13 years of age, with a positive predictive value of 87% by four years corrected age (Danks et al., 2012). Additionally, postural control and sensory motor function at four years post term were found to be fundamental areas of motor function impacting on long-term motor performance in non-disabled ELBW children. These findings reinforce the importance of assessment and intervention at four years of age.

2.1.4 Combined motor and functional impairments

It has already been mentioned that preterm and LBW children do not just have isolated motor difficulties but other functional impairments as well (Burns & Bullock, 1985; Foulder-Hughes & Cooke, 2003; Marlow et al., 1989; Van Hus et al., 2014). This co-existence of impairments can be explained by the dynamic systems theory of development and the interacting nature of systems and environments (Sweeney et al., 2010). At five years of age very preterm children who have motor impairments are likely to have complex minor neurological dysfunctions, low intelligence, slow processing speed, visual-motor coordination difficulties and hyperactivity issues (Van Hus et al., 2014). These problems

are likely to become quantitatively more significant when greater demands are placed on these children as they progress through school and beyond. Motor impairment amongst VLBW children at six years of age has been shown to be the best predictor of school failure at eight years with a high negative predictor value (Marlow et al., 1993). Marlow et al reported that a low motor impairment score at school entry correlated with satisfactory school performance, whereas children with a high motor impairment score had a 33% risk of learning problems. The rationale for this is unclear: it may be related to minor damage to the structure or function of the brain (Burns et al., 2004) or due to the inter-relationship between motor and cognitive development (Diamond, 2000). Further evidence highlighting the impact that motor performance has on later outcomes has been demonstrated by Cherry et al who found that behaviour problems amongst ELBW adolescents (11-13 years of age) were associated with their motor impairments rather than their prematurity (Cherry et al., 2013).

2.1.5 Relationship to developmental co-ordination disorder

The literature has commonly identified extremely preterm or ELBW children as having developmental co-ordination disorder (DCD). DCD, according to the DSM-V (Diagnostic and Statistical Manual of Mental Disorders, 5th edition), refers to minor motor difficulties that impact on learning and performance in daily activities, which cannot be explained by the child's age, intellect, or known physical disorder (American Psychiatric Association, 2000, 2013). Classifying preterm children as having DCD has been challenged as these children do have a medical and possibly a neurological reason for their motor impairment (Spittle & Orton, 2014).

There is a degree of variability across studies as to what percentile on assessment denotes DCD (Foulder-Hughes & Cooke, 2003; Goyen & Lui, 2009; Johnston et al., 2004). This variability may be related to the use of different motor assessment tools between studies and the lack of consistency in cut-offs used to quantify motor impairment (Davis et al., 2007). Using a total impairment score of less than or equal to the 15th percentile (greater than one standard deviation below the mean) on the Movement Assessment Battery for Children (MABC), it has been reported that 64% of five year old ELBW children had DCD (Dewey et al., 2011). Furthermore, Goyen et al reported that the prevalence of DCD (using the same cut-off to denote motor impairment) in 'apparently normal' eight year

old children born at less than 29 weeks' gestational age or less than 1,000g (Goyen & Lui, 2009) to be 42% compared with 8% in the full-term matched control group. In this latter study, motor assessment at three years of age of these 'apparently normal' children facilitated early identification of children likely to have DCD. This finding is important as intervention, where appropriate, could be implemented before formal education to minimise the risk of slow school progression for preterm children with DCD (Sullivan & McGrath, 2003). In the same group of 'apparently normal' preterm children, Goyen et al found that visual processing and praxis (with the exception of praxis on verbal command) were at a significantly lower level in the preterm group with DCD compared with the control group (Goyen et al., 2011).

It has been demonstrated that ELBW children with DCD are more likely to have an arithmetic learning difficulty than ELBW children without DCD (Holsti et al., 2002). Additionally, DCD and attention deficit hyperactivity disorder (ADHD) have been reported to co-exist in up to 50% of very preterm children (Foulder-Hughes & Cooke, 2003). A higher prevalence of behavioural issues amongst children with DCD has been identified by other authors as well (Davis et al., 2007; Hemgren & Persson, 2009). Davis et al compared the motor outcome of eight to nine year old extremely preterm or ELBW children with a normal birth weight cohort (Davis et al., 2007). A cut-off of less than the fifth percentile on the MABC (a definite motor problem) at eight years was used to classify DCD. The authors of this study reported DCD to be 9.5% in the extremely preterm or ELBW group compared to 2% in the normal birth weight group. The lower incidence of DCD found in this study compared to previously mentioned studies (Dewey et al., 2011; Goyen & Lui, 2009), may be related to the use of the stricter 5% MABC cut-off score. However, as well as concluding that DCD is more common in extremely preterm or ELBW children, Davis et al showed that DCD is associated with poor cognitive and academic performance and increased behavioural problems (Davis et al., 2007). Given that the *term* of DCD may not be properly applied to extremely preterm or ELBW children, the evidence suggests that problems similar to those in children with DCD are seen in the extremely preterm or ELBW cohort. This would suggest a pathway for intervention in the extremely preterm/ELBW group.

2.2 Effect of preterm birth on neurodevelopmental outcomes – postural stability

Preterm birth can have an adverse effect on postural stability. The following section will define postural stability and control, as well as the development of postural control, as this will assist with understanding how preterm birth can lead to poor postural outcomes.

2.2.1 Defining postural stability and postural control

Postural stability refers to the ability to control the vertical projection of the centre of mass (centre of gravity) in relationship to the base of support (Shumway-Cook & Woollacott, 2007). It maintains a stable background for movement. In the context of the trunk, it may be described as 'stiffness'. Anticipatory or feedforward muscle activity is responsible for providing this central stiffness or stability. Although anticipatory postural muscle activity is evident from 10 months of age, it is variable and its development may not be complete by 11 years of age (Bradley & Westcott, 2006). Poor postural stability affects skilled movements of the limbs and may also have central implications for body functions. In the absence of central and proximal stability, distal compensatory stability may need to be used, and subsequently, poor quality and efficiency of skilled movement and control may result. This concept of a link between postural stability and limb movement has been documented by Flatters et al, who concluded from the results of their study that there was an interdependent relationship between postural stability and manual skills (Flatters et al., 2014).

In order to understand postural stability, it is important to discuss postural control. Matiello and Woollacott, suggest that postural control can be viewed as a set of rules that couple sensory inputs with motor actions (Matiello & Woollacott, 1997). These actions control the variables of antigravity forces, intersegmental relationships and the maintenance of equilibrium, which form the foundations of postural control. According to Shumway-Cook et al, postural control involves controlling the body's position in space for the purpose of both stability and orientation (Shumway-Cook & Woollacott, 2007). If the centre of gravity is changed due to a perturbation, then balance strategies, such as equilibrium reactions, are employed to adjust the body in order to maintain balance. If a perturbation is expected, then anticipatory reactions may be utilised in addition to voluntary muscle action for efficient control of posture.

2.2.2 Development of postural control

The exact control mechanisms of posture remain unclear. Several theories have been suggested to explain the basis for the development of postural control. The central nervous system was initially thought to be responsible for postural development (Matiello & Woollacott, 1997). In this reflex-hierarchical theory, the emergence of posture and movement control relies on the appearance and disappearance of automatic infant patterns of movement. This is reflective of maturing cortical structures that inhibit and integrate automatic responses controlled at lower levels within the central nervous system so that more functional postural and voluntary motor actions emerge.

However, more recently, it has been suggested that the interaction of body systems (musculoskeletal and neural systems) and the environment are more pivotal to achieving mature postural control (Matiello & Woollacott, 1997). In this latter systems approach, which parallels the dynamic systems model previously discussed (Sweeney et al., 2010), the normal sequence seen in motor development does not rely only on the progression of central nervous system development from lower to higher levels, but rather, new behaviours emerge due to the interrelation of maturing systems (Matiello & Woollacott, 1997). For example, sensory systems contributing to postural control influence postural responses very early in development, with much of the literature suggesting that vision is the initiating and priority sense in the first few years of life (Matiello & Woollacott, 1997; Shumway-Cook & Woollacott, 2007). Once an infant learns how to organise synergistic muscles for controlling a position, such as stance, in association with one sense, this organisation does not automatically transfer to other senses (Shumway-Cook & Woollacott, 2007). Instead, it is modified according to further input from other senses (Shumway-Cook & Woollacott, 2007). For instance, even though the visual system will elicit postural responses in standing by five to six months of age (prior to somatosensory system mapping) the somatosensory system will develop its own postural synergies in association with somatosensory inputs signalling sway.

In further discussing development of postural control, an understanding of the variation and selection that is associated with the development of postural adjustments is important. Hadders-Algra, describes early postural activity as direction-specific, emerging in the neck

and trunk muscles at four to five months of age and the proximal limb muscles at six to nine months of age (Hadders-Algra, 2000). At this time, there is a degree of variability with respect to direction-specific postural adjustments to large perturbations. From 12 to 18 months of age, selection of the most efficient postural adjustments during minor perturbations of equilibrium, such as during reaching, occurs. All direction-specific neck, trunk, and proximal limb muscles are used less frequently as postural adjustments after two to three years of age. Instead, a collection of adjustments involving one to three muscles acting in concert emerge. Shumway-Cook et al refer to the period between four and six years of age as a transitional phase when responses are less consistent (Matiello & Woollacott, 1997). During this period, it has been shown that children have increased latency and variability in their responses to perturbation compared to 15-31 month old children and seven to 10 year old children. The regression between four to six years of age may be related to the fine tuning of the structural organisation of postural synergies, but also, to morphological changes that occur at this time (Matiello & Woollacott, 1997). Postural activity in older children is more consistent and efficient and is dependent on a mixture of automatic and learned responses.

2.2.3 Impact of preterm birth on postural control

In terms of the extremely preterm or ELBW population, evidence supporting reduced postural stability amongst teenagers has already been raised (Burns et al., 2009). However, other studies have demonstrated similar findings at younger ages (Bucci et al., 2015; Burns et al., 1999; Lorefice et al., 2014; Lorefice et al., 2012a; Matiello & Woollacott, 1997). In a study of infants born between 26-33 weeks' gestational age, it was identified that at two years corrected age, infants who had bronchopulmonary dysplasia (also referred to as chronic neonatal lung disease) had significantly poorer postural control (Burns, O'Callaghan, et al., 1997). When adjusting for growth, amongst children with a history of bronchopulmonary dysplasia, those whose weight was less than the 10th percentile demonstrated significant differences in postural control compared to those whose growth was within normal limits. More recently, Bucci et al confirmed that postural control at three to four years of age in children born very preterm (25-27 weeks' gestational age) is reduced compared to age-matched full-term peers (Bucci et al., 2015). In addition, Lorefice et al explored motor performance and postural control amongst four to five year old children born very preterm (less than 30 weeks' gestational age) and term

equivalent peers (Lorefice et al., 2014; Lorefice et al., 2012a). The authors concluded that very preterm born children have poorer motor outcomes, poorer static and dynamic postural control across a number of sensory conditions and reduced functional performance compared to their peers. At eight to 10 years of age, it has also been found that the postural stability of ELBW children is inadequate compared to that of typically developing children of similar age (Burns et al., 1999). Finally, Peterson et al have provided further evidence of postural control deficits amongst ELBW teenagers (Petersen et al., 2015).

2.2.4 Relationship between postural control and cognitive development

Postural control does not only influence the development of gross and fine motor skills but may be important for cognitive development (Spittle et al., 2009). Wijnroks et al examined whether individual differences in postural control at six months of age could predict cognitive development and attention in relatively healthy preterm infants six to 18 months later (Wijnroks & van Veldhoven, 2003). In this study, which included infants born less than 37 weeks' gestational age, it was found that infants with poor postural control at six months corrected age scored significantly lower on several cognitive measures and were significantly more often not attending to a task six to 18 months later when compared to those with adequate postural control.

2.3 Effect of preterm birth on neurodevelopmental outcomes – behaviour, cognitive function and attention

Behavioural problems, considered in a global sense, incorporate difficulties in self-regulation, including hyperactive or aggressive tendencies; interactive, attention, sleep, eating and sensory sensitivity difficulties; and anxiety, depression and somatic problems (Arpi & Ferrari, 2013). Prematurity and LBW can adversely affect attention, cognition and behaviour (Arpi & Ferrari, 2013; Bhutta et al., 2002; Marlow et al., 2005). It has been reported in the literature that over 50% of ELBW children show behavioural or social-emotional competence problems at 30 months (Peralta-Carcelen et al., 2013) and the rate of any neurobehavioural impairment has been reported to be as high as 71% amongst extremely preterm or ELBW children at eight years of age (Hutchinson et al., 2013). As

ELBW children progress into adolescence, behavioural problems have been reported to persist (Taylor et al., 2015).

2.3.1 Impact of preterm birth on attention in early childhood

Attentional difficulties have been identified as the potential precursor for the emergence of cognitive and behavioural problems amongst preterm children (Van de Weijer-Bergsma et al., 2008). Attention, which involves being able to orient to, move between and maintain concentration on information, tasks, objects and problems, relies on the functioning of attentional brain networks (Van de Weijer-Bergsma et al., 2008). There are three interconnected attention networks: orienting system or posterior network, alerting or arousal system and executive control system or anterior attention network (Van de Weijer-Bergsma et al., 2008). Attention is a higher order skill and is generally regarded as an executive function of the prefrontal cortex (Anderson et al., 2004).

Early attention development in infants born preterm is less favourable than that of full-term infants and the disparities in attention between these two groups becomes more apparent with age (Van de Weijer-Bergsma et al., 2008). Verkerk et al have provided further evidence of attention difficulties amongst VLBW children at preschool age and have identified that these difficulties predict school performance 2 years later (Verkerk et al., 2016). Van de Weijer-Bergsma et al proposed that both biological and environmental factors influence the development of attention in later years. For instance, these authors reported that differences in early orienting and sustained attention predicted attentional, cognitive and behavioural function. Additionally, in this study, it was suggested that children born preterm may have fewer successful experiences and fewer opportunities to learn than full-term children, and that the reduction in experiences could have a cumulative effect. Another reason for preterm children being susceptible to attentional difficulties may be related to brain maturation (interconnectedness) namely that as children are confronted with more challenging cognitive processes, minor difficulties become more pronounced. Moreover, differences may be related to the complexity of the environment with increasing age. Inefficient abilities may be challenged due to increased environmental demands. For example, behavioural problems may become more evident after a child enters formal education due to an inability to cope with the expectations of others (Hayes & Sharif, 2009).

2.3.2 Impact of preterm birth on attention at school age

Differences in attention at school age between children born preterm and children born at term equivalent age are well recognised (Brogan et al., 2014; de Kieviet et al., 2012; Geldof et al., 2013). The severity and specificity of attention problems in school aged children born very preterm compared to term peers was investigated in a study by de Kieviet et al (de Kieviet et al., 2012). The study confirmed that attention problems are more prevalent amongst school aged children born preterm compared to age-matched term peers. Furthermore, very preterm children had increased lapses of attention and deficits in visuospatial working memory, which suggests that attentional difficulties in this population are mediated by these neurocognitive functions. More recently, Brogan et al found that very preterm school aged children had significantly higher inattention scores than term equivalent peers (Brogan et al., 2014).

These conclusions in relation to attention are consistent with studies examining executive function (Anderson et al., 2004). Executive function is responsible for attention, but also plays a role in memory and learning, goal-directed behaviour, social skills and emotional control (Alduncin et al., 2014; Simeonsson & Rosenthal, 2001). Anderson et al investigated the frequency, nature and severity of executive dysfunction at eight years of age in ELBW or extremely preterm children compared with normal birth weight control children (Anderson et al., 2004). The authors demonstrated that the ELBW or extremely preterm group had significant executive dysfunction compared with the control group in all assessment areas including global differences across every cognitive parameter and behavioural impairments mainly in the area of metacognition. These findings could be related to disruptions to the vulnerable preterm brain during development. Network disconnections, such as damage to white matter, could provide another explanation for the results.

The executive functioning deficits amongst the ELBW or extremely preterm group evident in the Anderson et al study, were found to continue into adolescence and were persistent across multiple domains (Burnett et al., 2014; Burnett et al., 2015). Persistence of executive dysfunction challenges the suggestion by Ritter et al that problems related to executive function are more of a delay rather than a deficit (Ritter et al., 2013). However,

comparison between the findings by Burnett et al with those by Ritter et al needs caution as the studies differ, in terms of age of the children and degree of prematurity.

2.3.3 Impact of preterm birth on cognition, behaviour and learning

In the context of prematurity or low birth weight and school aged children, cognitive and behavioural consequences have been widely reported to co-exist (Adams-Chapman et al., 2015; Bhutta et al., 2002; Grunau et al., 2002; Hack et al., 1995; Hansen et al., 2002; Hayes & Sharif, 2009; Hutchinson et al., 2013; Marlow et al., 2005; Pugliese et al., 2013). A meta-analysis by Bhutta et al concluded that children born preterm were at risk of lower cognitive scores and an increased incidence of attention deficit hyperactivity disorder (ADHD) compared with children born at full term (Bhutta et al., 2002). Additionally, lower birth weight and gestational age were significantly correlated with lower cognitive test scores. Hansen et al also found that cognitive differences between VLBW children and term children persisted with time, with a lack of 'catch-up' of intelligence quotients (IQs) amongst VLBW children (Hansen et al., 2002). Furthermore, the authors concluded that specific learning problems and attention deficit tend to co-exist with low IQ score in low birth weight children. In a study by O'Callaghan et al investigating learning and attentional problems in ELBW children compared to a matched control group, it was concluded that school aged ELBW children have a high prevalence of learning difficulty (O'Callaghan et al., 1996). In this particular study, the risk of attention deficit disorder in ELBW children was not increased when compared to the matched control children. There is evidence in the literature highlighting the association between children born very preterm or VLBW and language difficulties (Reidy et al., 2013), as well as further verification of learning difficulties amongst this population, including a study by Grunau et al, which demonstrated that complex learning difficulties in multiple domains are common sequelae of ELBW (Grunau et al., 2002).

The academic difficulties that manifest amongst the ELBW population may be due to a mixture of neurocognitive deficits, especially in the areas of visuospatial, visual-motor and verbal abilities. Evidence to support this suggestion of neurocognitive deficits in ELBW children has already been raised (de Kieviet et al., 2012), but has also been reported in a study by Caravale et al (Caravale, Mirante, Vagnoni et al., 2012). Caravale et al showed that LBW children without neurological impairments had significantly lower visual-motor

and visual-perceptual scores than children born at term age. Similarly, Potharst et al, who investigated various neurocognitive functions in children born very preterm compared to those born at term age, found that (after controlling for sociodemographic characteristics) very preterm born children performed significantly poorer on visual-motor co-ordination tasks than term equivalent peers (Potharst et al., 2013).

2.3.4 Connection between cognitive and motor development in children born preterm

The range of neurodevelopmental impairments and their possible inter-relationship amongst children born very preterm or with ELBW has been briefly reviewed (Marlow et al., 1989; Van Hus et al., 2014). Diamond has also provided evidence of a link between cognitive and motor development and suggests that if either cognitive or motor function is affected, this often has an adverse impact on both areas of development (Diamond, 2000). The authors suggest that this is because the prefrontal cortex, through its various connections, may not only play a role in cognitive tasks, but may contribute to motor functions. In the same way, as the cerebellum appears to function in a circuit with the prefrontal cortex, it may be important for cognitive as well as motor performance. Additionally, both cognitive and motor development are equally protracted, with the prefrontal cortex and the cerebellum reaching maturity late. Therefore, prematurity may increase the risk of damage to an already immature prefrontal cortex and cerebellum, which may lead to motor and attentional problems. Abnormalities found in the cerebellum and the prefrontal cortex may assist in explaining why DCD symptoms and ADHD commonly co-exist in preterm children, with imaging showing unusual prefrontal cortex activity in people with ADHD (Diamond, 2000). Hadders-Algra has added to this finding of an inter-relationship between cognitive and motor impairments, suggesting that dysfunction to circuitries during the perinatal period may lead to complex minor neurological dysfunction, with a vulnerability to co-ordination, cognitive and attentional difficulties (Hadders-Algra, 2002). Jeyaseelan et al have demonstrated a close link between motor and cognitive function in their study in which they found an association between minimal to mild movement differences at two years of age and problems of attention at nine years amongst extremely preterm or ELBW school aged children (Jeyaseelan et al., 2006).

More recently, Van Hus et al explored the relationship between motor impairment and other developmental domains in a prospective cohort study comparing children born very preterm without disabling cerebral palsy to term born children at five years corrected age (Van Hus et al., 2014). The study found the incidence of motor impairment to be 32% amongst the very preterm children and 54% of these children had low IQ.

The use of the general movements assessment, based on the observation of spontaneous movements during the early post term period, has provided a catalyst for researchers to investigate possible links between early motor performance and later outcomes. The general movements assessment has been shown to be a sensitive and non-intrusive means of predicting impairments, with an abnormal general movements at three months associated with worse motor and cognitive outcomes at two and four years of age amongst children born very preterm (Spittle et al., 2013). It has been suggested that the general movements assessment may predict cognitive function in children born very preterm at seven to 11 years of age as well (Bruggink et al., 2010). This study did not explore motor outcomes.

2.4 Aetiology of neurodevelopmental problems amongst the preterm population

The aetiology of minor motor impairments, reduced postural control and problems of attention, cognition and behaviour amongst extremely preterm or ELBW children remains unclear. One way of reviewing these factors is to separate them into biological and environmental origins.

2.4.1 Biological factors

In terms of biological factors, birth weight has been reported as a common predictor of health and functional status, with lower birth weights leading to poorer developmental outcomes (Sullivan & Msall, 2007; Vieira & Linhares, 2011). Possible causes of low birth weight include intrauterine growth restriction, preterm delivery and genetic anomalies.

Another biological basis, which has already been discussed, is gestational age at birth (Anderson et al., 2004). The premature brain is vulnerable to damage particularly during

the perinatal period, such as injury due to hypotensive and hypoxic episodes (Sullivan & Msall, 2007). Small brain lesions may impact on motor and cortical pathways and thus the development of motor skills and executive function (Anderson et al., 2004; Sullivan & Msall, 2007).

Additionally, differences in size of various structures of the brain have been identified in preterm infants, with the corpus callosum area of the brain in very preterm adolescents found to be significantly smaller than that in term controls, especially its posterior quarter (Nosarti et al., 2004). Reduced volumes of posterior corpus callosum, as well as reductions in size of globus pallidus and cerebellar white matter have been discovered on cerebral magnetic resonance imaging (MRI) of non cerebral palsy ELBW children at 10 years of age (Grunewaldt et al., 2014). In terms of how these differences translate to a functional context, a significant correlation between verbal IQ and verbal fluency scores and the size of the posterior half of the corpus callosum has been demonstrated (Nosarti et al., 2004). These findings may be related to the later development of the posterior section of the corpus callosum and therefore its susceptibility to damage during the perinatal period. Injury to the corpus callosum may adversely affect fibre organisation and myelination as it plays a role in developing hemispheric lateralization of function (Nosarti et al., 2004). A recent study by Reidy et al has reinforced this idea of an association between white matter abnormality and neurodevelopmental outcomes, with the authors concluding that neonatal white matter abnormality (on neonatal MRI) is predictive of some impaired language abilities in children born very preterm or VLBW (Reidy et al., 2013).

Furthermore, it has been suggested that motor problems amongst very preterm children may be partially related to altered development of the posterior corpus callosum (Thompson et al., 2011). Other brain structural changes that may predict motor impairments in very preterm children include smaller brain volumes and internal capsule microstructure changes (Cheong et al., 2011). It is important to note that this emerging evidence has not been found to be independent of other perinatal factors. Further evidence from Spittle et al, who investigated whether neonatal white matter abnormalities were predictive of all levels of motor impairments in very preterm children, indicated that white matter abnormalities predicted motor impairment at five years of age and that rates of impairment increased with more severe white matter abnormalities (Spittle et al., 2011).

Deep grey matter growth amongst children born very preterm may predict neurodevelopmental outcomes (Young et al., 2015). Young et al showed that growth of the caudate and globus pallidus between birth and term-equivalent age of these children predicted visual-motor abilities at four years of age, with slower growth of these structures associated with poorer outcomes. The authors of this study also found that caudate and putamen growth were associated with IQ and language performance. A connection between thalamic growth and white matter lesions was demonstrated as well.

Morbidity during the perinatal period, such as episodes of infection, may further magnify the effect of brain injury on neurodevelopment (Dammann, 2001). It has been reported that preterm infants who have experienced both hypoxia and illness during the perinatal period are at an increased risk of problems of attention, hyperactivity and learning (McGrath et al., 2005). Furthermore, bronchopulmonary dysplasia (chronic neonatal lung disease) has been shown to be an independent risk factor for neurocognitive impairments amongst very preterm born children (Potharst et al., 2013) and has been found to be associated with abnormal motor performance at one and four years corrected age amongst non-disabled ELBW children (Zanudin, Burns, et al., 2013). It has already been mentioned that bronchopulmonary dysplasia is correlated with reduced postural control too (Burns, Gray, et al., 1997).

Gender has been proposed as a biological risk factor in extremely preterm infants, with males at greater risk of disability and learning difficulties (Marlow et al., 2005; O'Callaghan et al., 1996), as well as lower school-readiness levels (Oja & Jürimäe, 1997). In a study investigating the association between perinatal factors and outcomes of non-disabled ELBW children at 12 years of age, it was found that male gender correlated with later motor performance (Zanudin, Gray, et al., 2013). Additionally, Whitaker et al examined motor and cognitive performance in non-disabled adolescents born at less than 2,000g and concluded that male gender adversely influenced motor outcomes (Whitaker et al., 2006).

2.4.2 Environmental factors

In considering environmental factors, Ornstein et al conducted a review of neonatal follow-up studies of VLBW school aged children and found that low socioeconomic status

was the most commonly reported predictor of poor outcome (Ornstein et al., 1991). Furthermore, Hansen et al investigated whether school performance is poorer in LBW children beyond what could be caused by lower intelligence identified at four years of age (Hansen et al., 2002). It was shown in this study that low socioeconomic status was a significant predictor of school difficulties even after adjusting for general cognitive index. However, birth weight had no influence on school performance. Another study demonstrating the detrimental effect of an impoverished social environment on the development of premature infants was performed by Patrianakos-Hoobler et al (Patrianakos-Hoobler et al., 2009). In this study, multi-dimensional assessments were used to determine readiness of five to six year old children born prematurely for entry into school, and to identify factors contributing to lack of school readiness. It was concluded that the most powerful cause for decreased school-readiness levels was low socioeconomic status.

Despite evidence suggesting a link between socioeconomic factors and later performance, this link has been challenged in the literature, specifically in relation to motor outcomes (Goyen & Lui, 2009; Piek et al., 2008; Whitaker et al., 2006). In a study by Goyen et al, which has already been discussed, it was concluded that 'apparently normal' eight year old children born at less than 29 weeks' gestational age and/or less than 1,000g were at significantly higher risk of DCD, but their DCD was not associated with parental education or occupation (Goyen & Lui, 2009). Additionally, Piek et al considered the effect of socioeconomic factors in their study examining whether motor performance from birth to four years of age amongst low risk children (mean gestational age 37.5 weeks) predicted motor and cognitive performance at school age (Piek et al., 2008). Results indicated that although socioeconomic status predicted both cognitive and fine motor ability at school age, it was not predictive of school aged gross motor performance. Finally, in a study previously mentioned by Whitaker et al, social disadvantage was not found to be a predictor of motor outcomes amongst non-disabled adolescents born at less than 2,000g (Whitaker et al., 2006).

In further exploring environmental factors that may influence later outcomes in ELBW children, it is important to consider the parent-child interaction, which may have a compounding effect over time (Sajaniemi et al., 2001). Evidence suggests that a positive social environment may lead to more favourable outcomes for mature LBW children

(Bracewell & Marlow, 2002). Other factors that may impact on long-term developmental outcomes of LBW children include maternal education, age of mother, ethnic background of mother and marital status (Hack et al., 1995). Young et al demonstrated that maternal education levels were associated with measures of IQ and language skills of four year old children born very preterm (Young et al., 2015). Additionally, as well as maternal age and ethnicity of mother, a study by Gray et al showed that cigarette smoking in pregnancy and maternal psychological distress at 40 weeks' gestation, were significant predictors of behavioural problems in LBW children from three to eight years of age (Gray et al., 2004). More recently, Gray et al found that parenting stress in mothers of very preterm infants at one year of age was significantly greater than that of mothers of term infants and that depression and infant temperament were linked to parenting stress levels amongst preterm mothers (Gray et al., 2013). The outcomes of this study highlight the interdependent relationship between parenting stress and infant behaviour and the ongoing nature of parenting stress.

However, the possible link between maternal factors and neurodevelopmental outcomes has been challenged by O'Callaghan et al, who found that maternal education, maternal age and marital status were not significantly related to later learning difficulty in ELBW children (O'Callaghan et al., 1996). Additionally, Sommerfelt et al found that there were environmental and biological factors that had little influence on later behavioural problems in a study of five year old LBW children (Sommerfelt, Troland, et al., 1996). In particular, LBW children were not more sensitive to the adverse impact of parental risk factors and there was a lack of significant correlation between birth weight, gestational age, perinatal factors and postnatal factors and later behavioural outcomes. It needs to be noted that on the whole, the literature contesting the possible association between environmental and biological factors and neurodevelopmental outcomes is not as recent as that in favour of the association and therefore may be based on an era where technology was less advanced and survival rates were lower.

2.5 Comparison of performance between non-disabled preterm children and other cohorts of children - Developmental co-ordination disorder

There are a number of similarities between the performance of children born extremely preterm or ELBW who are labelled (perhaps incorrectly) (Spittle & Orton, 2014) as having DCD and children born at term age with DCD. In term age children with DCD, co-morbid issues are common, persistent in nature, and include behavioural problems (ADHD and autistic spectrum disorders), learning difficulties (in particular, language impairments and dyslexia), reduced self-esteem and social difficulties (Dewey & Wilson, 2001; Kadesjo & Gillberg, 1999; Rasmussen & Gillberg, 2000; Smits-Engelsman et al., 2013). Additionally, it has been shown that children with DCD born at term age have altered postural muscle activity (Johnston et al., 2002). ELBW children with DCD are more likely to have an arithmetic learning difficulty, behavioural issues such as ADHD, lower cognitive functioning, reduced sensorimotor skills and poorer postural control than non-disabled ELBW children without DCD (Burns et al., 1999; Burns et al., 2009; Davis et al., 2007; Foulder-Hughes & Cooke, 2003; Goyen et al., 2011; Hemgren & Persson, 2009; Holsti et al., 2002; Lorefice et al., 2012a; Matiello & Woollacott, 1997).

2.6 Outcomes of intervention amongst the preterm population

Intervention has been explored amongst the preterm population particularly during early infancy. The various types of intervention and resultant outcomes will be presented in the following section.

2.6.1 Early intervention

Intervention for the extremely preterm or ELBW population appears to be important to improve their overall outcomes. Early interventions, which take advantage of the plasticity of the brain at this time, have been provided for many years with varying degrees of success (Blauw-Hospers et al., 2007; Javier et al., 2012; Orton et al., 2009; Spittle et al., 2015; Spittle et al., 2007; Wu et al., 2014). Spittle et al performed a systematic review to determine the benefits of early developmental intervention pre or post hospital discharge (up to 12 months of age) on motor and cognitive development in preterm infants (born at

less than 37 weeks' gestational age) with no significant congenital problems (Spittle, Orton, et al., 2012; Spittle et al., 2015). In the most recent version of this review, 12 studies met the inclusion criteria (Spittle et al., 2015). Early intervention had a positive effect on cognition at infant age and at preschool age, but this was not sustained at school age. Early intervention had a favourable effect on motor outcomes in infancy, but there was little effect on longer term outcomes (only five studies reported on outcomes at preschool or school age). There was significant heterogeneity between the included studies and the sample sizes were generally small. The studies varied in terms of outcome measures, focus of intervention, method of delivery, dose and compliance. Furthermore, general limitations with intervention studies may have influenced the outcomes from this review including: blinding of the person providing the intervention is mostly impossible, some children may have been receiving additional treatments, and measures of motor performance that are often used did not specifically target minor motor difficulties.

2.6.2 Early intervention and the Infant Behavioural Assessment and Intervention Program (IBAIP)

The Infant Behavioural Assessment and Intervention Program (IBAIP) aimed at improving self-regulation of the infant, has been shown to have a positive impact on mental, motor and behavioural outcomes amongst VLBW infants at six months corrected age (Koldewijn et al., 2009). This conclusion was reached by Koldewijn et al, whose study was included in the systematic review by Spittle et al. In a more recent study by Koldewijn et al, the IBAIP showed sustained improvement on motor performance at two years corrected age (Koldewijn et al., 2010). A follow-up study of this randomised controlled trial at pre-school age, concluded that the positive outcomes of the IBAIP on executive functioning, behaviour and cognitive abilities were not maintained (Verkerk et al., 2012). However, there is evidence to support the IBAIP having sustained developmental effects on performance IQ, aiming and catching skills and visual-motor integration, which was demonstrated in a randomised controlled trial investigating the effect of the IBAIP in VLBW children at five years corrected age (Van Hus et al., 2013).

At two years corrected age, contrary to the beneficial effects of the IBAIP found by Koldewijn et al, such positive findings were not reached in a randomised controlled trial by

Kaaresen et al of children with birth weights < 2,000g (Kaaresen et al., 2008). In this latter study, early intervention, using a modified version of the Mother-Infant Transaction Program (comparable to the IBAIP) (Koldewijn et al., 2005), did not improve cognitive, motor or behavioural outcomes (Kaaresen et al., 2008). However, in a further follow-up study of these children at five years corrected age, there was a reduction in behavioural problems reported by parents (Nordhov et al., 2012). The variation in these findings emphasises the need for long-term follow-up when evaluating the potential benefits of intervention programs.

2.6.3 Preventative care program

The effectiveness of a preventative care program delivered at home over the first 12 months of life for very preterm infants was examined by Spittle et al (Spittle et al., 2010). Intervention involved nine home visits and focused on infant development (cognitive, motor, and language), behaviour, parent-infant interactions and the parents' mental health. The control group received standard care. At two years corrected age, the program had no significant effect on cognitive, language or motor development, but there were improved behavioural outcomes for infants and decreased anxiety and depression for primary caregivers. These positive effects were both maintained at four years corrected age (Spittle, Spencer-Smith, et al., 2012). Due to the ongoing nature of neurodevelopmental problems in preterm infants and the need for intervention that has a lasting effect, further reassessment of the children and families in this study will be important.

2.6.4 Early intervention and the Newborn Individualised Developmental Care and Assessment Program (NIDCAP)

The effect of early intervention has also been examined in a systematic review by Blauw-Hospers and Hadders-Algra (Blauw-Hospers & Hadders-Algra, 2005). In this study, intervention commenced between birth and 18 months corrected age and targeted motor outcomes. The study concluded that the Newborn Individualised Developmental Care and Assessment Program (NIDCAP) (focuses on specific motor training) may have short-term motor benefits prior to term age. Additionally, specific or general developmental programs may lead to short-term motor benefits post term age. However, this study included infants

at high risk for, or with, developmental motor disorders, and was not primarily targeted at preterm infants.

NIDCAP and the Synactive Model of Newborn Behavioural Organization and Development, form the bases for the development of the IBAIP (Koldewijn et al., 2005). In continuing their research into early intervention for high risk infants, Blauw-Hospers et al have provided some evidence to support Coping with and Caring for infants with neurological dysfunction – a family centred programme (COPCA) (Blauw-Hospers et al., 2007). COPCA is centred around the Neuronal Group Selection Theory (Edelman, 1987) and on new findings in education and family care. Blauw-Hospers et al concluded that COPCA, when applied between three and six months corrected age, may have sustained improvements on developmental outcomes until 18 months, specifically in terms of sitting performance and cognitive function.

2.6.5 Role of parents in intervention

Early intervention studies in which the parents play a key role have shown some beneficial effects. Vanderveen et al investigated whether interventions that involve parents improve neurodevelopmental outcomes at 12 months corrected age or older for preterm or LBW infants (Vanderveen et al., 2009). In this systematic review, intervention included parent education, infant stimulation, home visits or individualised developmental care, with the intervention commencing during the first year of life. Positive effects on neurodevelopment were found to 36 months of age but not at five years. The interventions had a greater impact on mental rather than physical performance, which may have been related to the nature of the interventions. However, in this systematic review there was significant heterogeneity between the studies, the methodological quality of the studies was low and the outcome measures used may not have been sensitive enough to detect change over time.

Additional evidence indicating that parents may play a pivotal role in intervention amongst VLBW infants has been described by Wu et al (Wu et al., 2014). The authors performed a randomised controlled trial exploring the impact of a clinic-based intervention program and a home-based intervention program compared with standard care. The intervention period was from hospitalisation until 12 months of age. It was found that

mother-infant interaction and infant emotional regulation may influence cognitive and behavioural outcomes respectively.

2.6.6 Group-based intervention

There is some evidence in the literature examining the effects of group-based physiotherapy intervention amongst older children of differing populations. Group therapy is important from an educational perspective as it provides opportunities for social interaction and enables a larger number of children to access intervention in a shorter timeframe (Watter & Bullock, 1989). Watter et al investigated the effect of a physiotherapy directed school-based program for primary school children with minimal brain dysfunction, an earlier term used to describe children with DCD (Watter & Bullock, 1989). Eighty-four children were included and were drawn from all grades in the school. Eligible children had mild difficulties with age appropriate gross motor skills, fine motor skills or eye-hand co-ordination, which, overall, impacted on functional performance. The program was provided by a physiotherapist and delivered by school personnel, utilised an activity based approach, was conducted for 20-30 minutes three times per week and continued for three to six months. Groups contained between three and seven children. Children were re-assessed after three months and then again after six months. There was significant improvement in 60% of the children after three months but changes from three to six months were less marked. Changes from initial assessment to final assessment were significant in all of the major areas. Therefore, this study demonstrated that group therapy can be beneficial for children with minor motor dysfunction and is also cost-effective.

More recently, Johnston et al performed a randomised controlled trial to determine if a school-based physiotherapy program to improve postural muscle function would enhance motor performance in eight to 10 year old children with DCD (Johnston et al., 2004). An impairment score of less than or equal to the 15th percentile on the MABC was used to classify DCD. Intervention consisted of activities designed to activate postural muscles of the trunk, shoulder and hip. The program occurred at school for 30 minutes twice per week and continued for eight weeks. Children in the non-intervention group continued routine daily activities and had no other therapy. One hundred and ten children were included. Results of the study showed that children with DCD who received intervention had a reduction in impairment and balance. Therefore, it was concluded that group-based

physiotherapy to improve postural control has a positive effect on motor co-ordination for children with DCD.

Piek et al explored the impact of group therapy amongst four to six year old children in a randomised controlled trial (Piek et al., 2013). Intervention was based on the Animal Fun program where the movements of animals are imitated with the goal of improving the child's motor ability and social skills, as well as their perceptions of their motor performance. The intervention was led by teachers who had undergone training and the program was incorporated into the normal curriculum for 30 minutes a day, four days a week for a minimum of 10 weeks. In this study, six intervention and six control schools were compared six months post intervention and then again 18 months post baseline assessment. Piek et al found that only the intervention group made gains in motor performance. The program also appeared to be effective in terms of improving social skills and behaviour (Piek et al., 2015).

Further evidence indicating the value of group therapy intervention has been reported by Auld et al who conducted an intervention study in which a physiotherapy group-based exercise program for children with cerebral palsy was used to target balance and strength (Auld & Johnston, 2014). Children were aged eight to 15 years old with Gross Motor Function Classification System scores ranging from I-III. Intervention involved a community-based gym group program for one hour per week for eight weeks. Activities focussed on improving upper limb, lower limb and trunk strength, and static and dynamic balance. As a result of the program, strength and balance gains were achieved. However, only 10 children were included in this study.

Group-based therapy and the role of core stability training has been explored as well (Shirt et al., 2013). Although the study was a pilot trial with small numbers (five children), Shirt et al found that specific core stability training improved balance and postural control in children aged four to seven years with motor and co-ordination deficits. Children underwent eight weekly sessions in a group format, with each session 45 minutes in duration. The program targeted strengthening of core stability muscles, including transverse abdominus activation, as well as balance. Another pilot trial focusing on core stability training was conducted by Au et al (Au et al., 2014). In this randomised controlled pilot trial, the effectiveness of a core stability program (based on the process-oriented

approach) was compared to a task-oriented program in children aged six to nine years with DCD (impairment score of less than or equal to the 15th percentile on the MABC-2). Twenty-two children were included. Children in both groups made significant improvements in motor proficiency. These findings challenge recommendations from a combined systematic review and meta-analysis by Smits-Engelsman et al that investigated the effectiveness of motor interventions for children with DCD (Smits-Engelsman, et al., 2013). In this meta-analysis study, task-oriented and traditional motor-training-based therapies had strong treatment effects, whereas process-oriented therapy, which focuses on components or body functions required to perform activities, had a weak treatment effect. However, Smits-Engelsman included studies that were not just group-based.

Further evidence supporting group-based therapy and the task-oriented approach can be drawn from a study by Farhat et al (Farhat et al., 2016). Children in this study (41 children) had DCD (impairment score of less than or equal to the 15th percentile on the MABC-2) and were aged between six and 10 years. Therapy involved a group-based task-oriented skills training program three times per week for eight weeks. The program addressed motor difficulties commonly experienced by children with DCD. As a result of the intervention, practiced and non-practiced skills improved. These findings indicate that there was an improvement in motor skill, as well as perhaps a transfer effect of these gains to other skills. It has been suggested that generalisation of treatment benefits may be more likely to occur during childhood because the differentiation process has only just commenced (Schoemaker et al., 1994).

It has been proposed that children with border-line motor dysfunction may be more responsive to group-based therapy than children with definite motor problems (Pless et al., 2000). This conclusion was reached in a study examining the effect of group-based intervention in addition to consultative services amongst five to six year old children with DCD (this study used an impairment score of less than or equal to the 15th percentile on the MABC).

2.7 Justification for the proposed thesis study

It appears that no studies have explored the outcomes of group-based intervention amongst children four to five years of age who were born extremely preterm or ELBW with mild neurodevelopmental problems. Further research is required in this area for a number of reasons, most of which have already been discussed. Firstly, in terms of development, the period between four to six years of age has been referred to as a transitional phase (Shumway-Cook & Woollacott, 1985). Therefore, intervention towards the commencement of this period may have a greater impact than at other ages and may also facilitate progression to the next phase.

In addition, extremely preterm or ELBW children who escape major disabilities are at high risk of neurodevelopmental problems which tend to be persistent and have considerable consequences (Bracewell & Marlow, 2002; Burns et al., 2004; Burns et al., 2009; Danks, 2010; Goyen & Lui, 2009; Hack et al., 2002; Keller et al., 1998; Powls et al., 1995). In the school setting, these impairments are detrimental, especially in terms of impact on academic functioning and social success (Reijneveld et al., 2006); (Bhutta et al., 2002). It has been reported that over 50% of eight year old children born at less than 30 weeks' gestational age who were receiving mainstream education, required additional assistance in some form (Wocadlo & Rieger, 2006). Moreover, studies involving four year old children have demonstrated the predictive value of performance at this age, suggesting that improvements at four may lead to long term benefits (Danks et al., 2012; Hansen et al., 2002; Sullivan & McGrath, 2003; Sullivan & Msall, 2007).

Furthermore, concerns about the preparedness of these children for the demands of the classroom when commencing formal education have been raised (Patrianakos-Hoobler et al., 2009; Prichard et al., 2012; Roberts et al., 2011). School readiness has been defined as being prepared to undertake learning of skills, including reading, writing, and responding to instructions appropriately, as well as having the ability to engage socially and to be independent in daily activities (Patrianakos-Hoobler et al., 2009). In a school-readiness study, Patrianakos-Hoobler et al found that 33% of premature children were not ready for school (Patrianakos-Hoobler et al., 2009). Additionally, Roberts et al investigated the school readiness skills of very preterm children compared to term controls and concluded that 44% of the very preterm group had vulnerabilities in more than one

school readiness domain compared to 15% of the term controls (Roberts et al., 2011). Concerns regarding lack of school-readiness has particularly occurred in recent times with a preparatory year or 'prep' year replacing 'preschool' in Queensland where children start a full-time school program as early as four and a half years chronological age. The importance of considering school readiness has been further reinforced by Doyle et al, who have highlighted that problems are more likely to occur for higher risk children at transitional points such as the commencement of formal education (Doyle et al., 2014).

In regards to intervention, it can be argued that group-based therapy is of greater relevance as it is more aligned with the school setting where children need to interact with their peers. Involvement of parents in their child's intervention is also important as this interaction has been shown to have advantages (Vanderveen et al., 2009). Therefore, if intervention is provided to non-disabled extremely preterm or ELBW children, it may better prepare these children for school and in the long term, improve their quality of life. The use of outcome measures that assess motor performance, postural stability, behaviour and cognition, would be particularly useful in determining the efficacy of intervention amongst this cohort of children.

With these issues in mind, a pilot study was conducted in 2008-2009 investigating the benefits of a six week group-based physiotherapy intervention program for four to four and half year old children born extremely preterm or ELBW (Burns et al., 2010). In this pre-post intervention study, nine children completed the program. Results showed significant improvement in motor co-ordination (measured by the MABC-2), as well as balance, postural stability and strength improvements. From the parents' perspective, there were improvements towards achieving parent goals, and overall there was a high level of satisfaction amongst parents about the program. These findings suggested advantages of intervention prior to school for extremely preterm or ELBW children and thus the need for further research.

CHAPTER 3

DESIGN, MEASUREMENTS & METHODOLOGY

This chapter will present and discuss the design, measurements and methodology of the thesis studies.

3.1 Design

The initial study was a prospective-descriptive-cohort-study, which explored the performance of all non-disabled extremely preterm or ELBW children eligible to participate in the study at a corrected age of four years. In addition, this study described in greater detail, the characteristics of the sample of children who consented to participate in the study. The remainder of the studies were those that were conducted in a randomised controlled trial (RCT) format in accordance with the CONSORT statement (CONSORT: Transparent Reporting of Trials, 2010). The RCT was a standard two-group parallel design, with an intervention group and a standard care group. The trial was registered with the Mater Research Registry and the Australian and New Zealand Clinical Trials Registry (ANZCTR). ANZCTR Trial ID: ACTRN12613000950763.

3.2 Measurements used for assessment and reason for selection of these tools

Outcome measures were identified that could evaluate the developmental aspects of poor developmental performance highlighted in chapter 1. Thus tests of motor performance, functional postural control and strength, behaviour, visual-motor skills and cognition were identified. Furthermore, outcome measures were selected in alignment with the ICF model (World Health Organization, 2001) and were used to determine if planned intervention was effective. Body function and structure, activity limitations and participation restrictions for the individual were considered in the selection of these measures, as well as personal factors. Measures of postural control/strength, behaviour, visual-motor skills and cognition addressed body function and structure, whilst motor

performance provided an indicator of activity limitations. Demographic details, examined in detail in the initial study, targeted personal factors, as did goal setting in the intervention group.

3.2.1 Measures of motor co-ordination

The Movement Assessment Battery for Children-Second Edition (MABC-2), a test of motor co-ordination (Henderson et al., 2007) was used, being the most widely recognised and suitable tool, despite some previously reported limitations. The MABC-2 is a revision of the Movement Assessment Battery for Children (MABC) and is a standardised test for children and adolescents from three years of age through to 16 years of age (Brown & Lalor, 2009). It is designed to assess, identify and describe movement difficulties and can be used to measure change as a result of intervention (Henderson et al., 2007). It provides quantitative and qualitative data.

Although it has been reported that there is no 'gold standard' screening tool for identifying DCD (Crawford et al., 2001), the MABC has frequently been used as a norm-ranked assessment for determining DCD in school-aged children (Crawford et al., 2001; Johnston et al., 2004) and the test-retest reliability of this instrument is acceptable (Brown & Lalor, 2009; Henderson et al., 2007). The MABC was ranked the highest in a systematic review evaluating the clinimetric properties of performance-based gross motor tests for children with DCD (Slater et al., 2010). Studies of the Test of Motor Impairment (Stott et al., 1984), the predecessor of the MABC, indicate that it was reliable and useful in identifying children with motor problems (Crawford et al., 2001). The MABC also appears to identify more readily those children who have additional learning or attentional difficulties and it includes qualitative descriptors (Crawford et al., 2001). Finally, the MABC, and the MABC-2, have commonly been used in studies involving premature or low birth weight infants (Burns et al., 2008; Burns et al., 2010; Burns et al., 2009; Foulder-Hughes & Cooke, 2003; Goyen & Lui, 2009).

Additional strengths of the MABC-2 include the revisions that have been incorporated so that it is more applicable to a wider range of children and adolescents, particularly those with motor impairments associated with preterm birth that are not as severe as cerebral palsy (Brown & Lalor, 2009). Furthermore, individual component scores of the MABC-2

have been shown to be reliable and have acceptable correlation with each other and the total test score (Henderson et al., 2007). Therefore, when interpreting performance on the MABC-2, it is meaningful to consider each of the three subsections (manual dexterity, ball skills, and static and dynamic balance) independently, as well as considering the total standard score.

Limitations associated with the MABC-2 include the lack of high quality evidence supporting its reliability and validity, its potential to penalise children with attentional problems, it may lack sensitivity to change, and although it may reveal that a child cannot perform, it does not explain why this is the case (Brown & Lalor, 2009; Crawford et al., 2001). Although there is some evidence to support the reliability and validity of the MABC, there are fewer studies that have addressed these issues with the MABC-2 (Brown & Lalor, 2009; Henderson et al., 2007; Smits-Engelsman et al., 2011; Wuang et al., 2012).

The Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) (Bruininks, 1978) is the other motor test that was considered for the purpose of this thesis, but was not utilised for a number of reasons. Only moderate concurrent validity was reported between the MABC and the BOTMP in identifying DCD in eight to 17 year olds, but the lack of consistency between the tests may have been related to variations in test structure and style (Crawford et al., 2001). An important difference between the two tests is that the MABC focuses more on motor skills, whereas the BOTMP aims to characterise motor abilities (Crawford et al., 2001). It has been suggested that the BOTMP may under-identify children with motor problems and investigators have questioned its validity and reliability (Crawford et al., 2001). Additionally, the BOTMP is designed to be used with children from four and a half years of age and some children included in the current study series were younger than this at initial assessment.

The Bruininks-Oseretsky Test of Motor Proficiency (2nd Edition) (BOT-2) (Bruininks & Bruininks, 2005) is a revised version of the BOTMP. One aim of the BOT-2 was to improve testing amongst four and five year old children and to identify motor skill difficulties in children with mild to moderate motor control problems. However, some test items in the BOT-2 are still rather challenging for typically developing four year olds and for five year olds with developmental delay (Deitz et al., 2007). Additionally, the BOT-2 is time-consuming to perform and the score conversion is complicated (Slater et al., 2010).

In the systematic review by Slater et al that has been previously mentioned, it was ranked the third highest motor test for children with DCD (Slater et al., 2010).

Therefore, for this thesis, the MABC-2 was identified as the most clinically suitable instrument for assessing motor co-ordination.

3.2.2 Functional measures of postural stability and limb strength

As well as a global measure of motor performance, more focussed tests relating to functional postural control and strength skills were included. Timed single leg stance and lateral reach test were used to measure functional postural control and balance and standing long jump was used to assess functional lower limb strength and control. Although few measurements of postural stability in children are available that are reliable and valid (Westcott et al., 1997) and norms for these tests are lacking, the above mentioned tests are functional, commonly applied in the clinical setting and have been used to varying degrees in children with DCD and cerebral palsy, as well as with ELBW children (Auld & Johnston, 2014; Burns et al., 2010; Burns et al., 2009; Johnston et al., 2004).

It has been demonstrated that the lateral reach test is a reliable and valid measure of medio-lateral postural stability in adults (Brauer et al., 1999). Furthermore, it has been reported that the Paediatric Reach Test (PRT), which incorporates a modified functional reach test and lateral reach test, is a simple, valid and reliable measure for use with children (Bartlett & Birmingham, 2003). Additionally, the PRT was shown to be a reliable measure for assessing the limits of stability in hearing impaired children (Rajendran et al., 2012). Oja et al have provided evidence to support the reliability of the standing long jump as a measure of explosive strength amongst four and five year old children (Oja & Jürimäe, 1997). In relation to the timed singled leg stance test, excellent test-retest reliability was shown in a study investigating test-retest reliability of postural stability measures in typically developing and in hearing impaired children (De Kegel et al., 2011).

3.2.3 Measures of functional performance

The Goal Attainment Scaling (GAS) (Kiresuk et al., 1994) was utilised for the intervention group in the RCT. The GAS is a valid and reliable test of individualised performance outcome and program evaluation and has been found to be suitable for young children with or without motor delays (King et al., 1999; King et al., 1998; McLaren & Rodger, 2003; Palisano, 1993). This criterion-referenced test measures qualitative change and small but clinically meaningful gains in motor development and function, and can also quantify change (Palisano, 1993). It has been demonstrated that the GAS is suitable for evaluating the effects of intervention for children receiving therapy at school and that considering functional goals is beneficial and ultimately results in improvements in children's functioning (King et al., 1998). The GAS was utilised in a pilot study assessing the effect of functional training amongst children (aged 18 months to six years) with CP (Ahl et al., 2005). In this study, 77% of goals were attained, indicating personal gains but also efficacy of the intervention. Criticism about the GAS has been related to its potential for bias, which may manifest in the form of the therapist participating in the goal setting process to set goals that will be easily achieved. However, collaborative goal setting between the family and the therapist, the use of an independent therapist performing the goal rating and peer review of the GAS scales, assists in avoiding this from occurring (King et al., 1999). These steps, along with other recommendations to improve reliability and validity (McDougall & King, 2007) were followed in this study series.

3.2.4 Measures of behaviour

The Child Behavior Checklist for Preschool Children (CBCL/1 ½ -5) was used to further explore the performance of extremely preterm or ELBW children at four to five years of age and to determine whether behaviour changed after intervention or over time. The CBCL assesses the frequency of behavioural and emotional problems (Achenbach & Resorla, 2000). It is a standardised test completed by parents and is normed on national samples of children from the United States of America. There is evidence to support the validity and reliability of the problems scales of this test (Achenbach & Resorla, 2000). The CBCL has commonly been used in studies investigating behavioural and/or emotional outcomes of VLBW or very preterm children (Hayes & Sharif, 2009). The CBCL was selected over other behavioural tests as it can be completed fairly quickly and, unlike many standardised forms, the CBCL includes qualitative elements as there are questions requesting explanatory details. Also, the CBCL provides standardised ratings of diverse

aspects of functioning, including functioning in the home, educational and social settings, and in this way closely aligns with the ICF framework. There is increasing interest in the value of parent questionnaires to identify problems in children due to increasing costs of formal professional assessment. However, potential limitations associated with questionnaires where the parent is the informant include over estimation or under estimation of the child's problems. Due to the age of the children included in the study series, self-report and teacher report were not suitable. Therefore, parent report was the only option.

Other behaviour-rating scales that were considered included the Behavior Assessment System for Children Second Edition (Reynolds & Kamphaus, 2004), which has been criticised for underestimating a child's behaviour (Myers et al., 2010), and the Clinical Assessment of Behavior (Bracken & Keith, 2004) (Bracken 2004), which has limitations including no separate form for pre-schoolers (its age range for the one form is two to 18 years of age).

3.2.5 Measures of visual-motor skills

The Beery Visual-Motor Integration (VMI) Test 5th Edition was used to test for visual-motor deficits as this aspect has been identified as a possible reason for co-ordination difficulties in children (Beery et al., 2004). The test examines the extent to which children can integrate their visual and motor abilities. The Beery VMI is norm-referenced and quick to administer. High reliability and validity has been reported for the Beery VMI (Beery et al., 2004). When used with other measures, the Beery VMI has also been reported to be a good predictor of academic performance. The Beery VMI has been used in studies examining neuropsychological outcomes of preterm children without neurological disabilities (Caravale et al., 2012; Goyen et al., 1998). The Beery VMI was selected for use as it has been cited in several studies of very preterm/VLBW children (Geldof et al., 2012).

3.2.6 Measures of literacy skills

The Peabody Picture Vocabulary Test 4th Edition (PPVT-4), an individual standardised intelligence test, was used to measure receptive (hearing) vocabulary for Standard English

and to provide an estimate of verbal ability or scholastic aptitude (Dunn & Dunn, 2007). In other words, it assesses comprehension of the spoken word and evaluates an individual's accomplishment in vocabulary acquisition. This information is indicative of a child's linguistic skills and cognitive level and is therefore useful in the context of school readiness. The PPVT-4 is a norm-referenced test based on a sample of people from the United States of America aged two and a half years old through to adulthood. Modifications in the 4th Edition include easier items at lower ability levels to assist with accuracy and full-colour pictures instead of black-and-white pictures. Strengths of the PPVT-4 are that it is untimed and it is individually administered. Additionally, only items that are in the individual's critical range or vocabulary level need to be assessed, therefore it is brief and time efficient and scoring is quick and simple. Another strength of the PPVT-4 is that the standard score scale is the same as that used in numerous other tests enabling easy comparison with scores on tests of language, achievement and ability. However, care needs to be taken not to overgeneralise when using this test as it only assesses one aspect of language development. The reliability of the PPVT-4 is of a high level and there is strong evidence supporting its construct and predictive validity. Studies of preterm and ELBW children have utilised the PPVT as an outcome measure (Adams-Chapman et al., 2015; Caravale et al., 2012). All of the children in the current study series had already undergone the Stanford-Binet test (Roid, 2003) at their four year (corrected age) Growth and Development Clinic review, therefore this test could not be used and, as already mentioned, the PPVT addressed the language component.

3.3 Methodology for proposed studies

The following section will present the methodology of the thesis studies including ethical considerations, inclusion/exclusion criteria, procedural details, description of measurements and protocols used and data analysis.

3.3.1 Ethical considerations

The Mater Health Services Human Research Ethics Committee (reference number: 1496C) and the Medical Research Ethics Committee of the University of Queensland (approval number: 2010000505) granted approval for all studies, including the randomised

controlled trial (Appendix 1.1). Information about the trial was provided to parents/guardians of eligible children both verbally and via written material (Appendix 1.2). Written informed consent was obtained from all parents/guardians prior to children commencing involvement in the trial (Appendix 1.3). All data were de-identified prior to analysis and was stored in a secure location.

Children were accompanied by a parent/guardian at all times when undergoing assessment and/or when participating in the intervention program. If a child refused to perform an assessment item or activity within the intervention program, in consultation with the parent/guardian, this decision was respected. Families who requested feedback about their child's performance in the assessments were provided with a written report containing this information.

3.3.2 The cohort

Inclusion criteria

The participants were born less than 1,000g and/or less than 28 weeks' gestational age and were managed in the Neonatal Intensive Care Unit at the Mater Mothers' Hospital, Brisbane, Australia. Children were aged four to four and a half years corrected for prematurity when commencing involvement in the study and had not started their preparatory (prep) year of schooling (commencement of formal education in Queensland). Children who were included lived within one hour travel to the Mater Hospitals. Additionally, participants had attended their four year (corrected age) Growth and Development Clinic follow-up assessment (born between 2005 and 2008) and had a score from the Neurosensory Motor Developmental Assessment (NSMDA) of 9 to ≤ 12 and an IQ of > 70 on the Stanford-Binet test.

The NSMDA is a criterion-referenced assessment tool of gross and fine motor performance, postural development, neurological characteristics and the motor responses to sensory input (Burns, 2014). It therefore incorporates most elements of the dynamic systems model and provides information on overall development (Thelen & Smith, 1994). A score of 9 to ≤ 12 indicates minimal to mild deviation from age expected motor performance. NSMDA score at four years corrected age is of particular relevance as it

has been shown to independently predict motor co-ordination at 11-13 years of age with a positive predictive value of 87% (Danks et al., 2012).

The Stanford-Binet Test is a standardised test used by Psychologists to assess intelligence and cognitive abilities and is suitable for children aged two years to 85 plus years (Roid, 2003). A score of <70 corresponds to an IQ classification of delayed development.

Exclusion criteria

Children with significant congenital anomalies, diagnosed neurological impairments including cerebral palsy, a visual impairment not corrected by wearing corrective lenses or a hearing impairment not corrected by aids, were excluded. Children were not eligible to participate if their parents/guardians did not speak English, as delivery of the program and follow-up telephone calls, required answers in English so would not have been practical. Children of families who identified that they would not be able to commit to attending a six week physiotherapy program and returning for follow-up assessments, were also excluded.

3.3.3 Measurements & protocols

Independent paediatric physiotherapists were trained in administering the assessments. The assessors used a set training protocol that involved a consistent order for the various assessments performed. The assessors received no background information about participants except for their date of birth and expected date of birth. The assessors had no involvement in the intervention or standard care of the children and were blinded to group allocation. Assessment of each child was performed on an individual basis and took approximately one hour per child. The intervention program was supervised by the researcher/author.

MABC-2

Participants underwent the MABC-2 testing in accordance with the guidelines and conditions described in the test manual (Henderson et al., 2007). As previously mentioned, the MABC-2 consists of three subsections: manual dexterity, ball skills, and static and dynamic balance. The test is divided into three age bands (3:0-6:11 years, 7:0-

10:11 years and 11:0-16:11 years). In order to assess each component (manual dexterity, ball skills, and static and dynamic balance), eight age-appropriate physical test items are assessed. Raw scores for each item are converted into standard scores. Within each component, these standard scores are added to form component scores. Following this, component scores are converted into standard scores and percentiles. The eight item standard scores are summed to determine the total test score and percentile rank. Performance can be compared to established norms. A percentile rank between the fifth and 15th percentile was used to indicate borderline motor difficulties and less than or equal to the fifth percentile corresponded to a definite motor problem (Henderson et al., 2007).

Timed single leg stance, lateral reach and standing long jump

For these tests, participants were tested barefoot and were given three trials per side of the body for timed single leg stance (recorded in seconds) and lateral reach test (recorded in centimetres), and three trials for standing long jump (recorded in centimetres). The best performance on each test was used. A set protocol with standard instructions was applied when administering these tests. In assessing single leg stance, timing commenced when the child lifted the nominated leg, the free foot was not allowed to touch the other leg or floor, and eyes remained open during the test. For lateral reach, the child stood in front of a wall (with back facing but not touching the wall) with feet shoulder width apart and with one arm raised to 90 degrees of abduction. The child then reached as far sideways to that side as possible whilst maintaining balance and a fixed base of support. The child was not permitted to lean against the wall. The distance reached was determined by the difference between arm's length and maximal lateral reach of the finger tip of the third finger (Bartlett & Birmingham, 2003). When testing standing long jump, the child first stood with their toes just behind a marked take-off line. The child then crouched and sprung forwards as far as possible, but had to land two feet together and not overbalance. The horizontal distance jumped was measured from the take-off line to the point of the child's two feet that landed closest to the starting point (Oja & Jürimäe, 1997).

GAS

The GAS was undertaken by the intervention group only (King et al., 1999). The GAS procedure involves defining an individualised set of goals for each child, identifying a range of possible outcomes for each goal (on a scale from -2 to +2) and using the scale to determine the child's functional change after a specified intervention period (King et al.,

1999). Goal setting occurred between the parents/guardians and an independent paediatric physiotherapist who was not the principal physiotherapist conducting the intervention. Goals were meaningful to the family, measurable, attainable and time-limited. Three goals were established for each child and these aimed to address action, function and performance. For each goal, a written description of the child's baseline level of performance was recorded (corresponding to a -2 rating), as well as an expected level of performance (corresponding to a 0 rating) and a more/much more than expected level of performance (corresponding to a +1 or +2 rating) following completion of the program. The GAS scales were peer reviewed by a research assistant. Goals were re-assessed at the completion of the intervention program and up to three trials were permitted when testing each goal. The independent physiotherapist, in collaboration with parents, performed the goal rating.

CBCL

The CBCL/1 ½ - 5 requests demographic details and rating, by parents/guardians, of 99 problem items on a 3 point scale (Achenbach & Resorla, 2000). Problem items are converted into syndrome scale scores which can be classified as borderline clinical range (93rd to 97th percentile), clinical concern (above the 97th percentile) or normal (less than the 93rd percentile). Each syndrome scale score has a corresponding T score, which is a standard score that has a consistent meaning for each scale. Additionally, scoring involves calculating an internalizing and externalizing score which are based on groupings of syndromes. The internalizing score is associated with problems that are mainly within the self and consists of the syndromes emotionally reactive, anxious/depressed, somatic complaints and withdrawn. The externalizing score represents problems that involve conflicts with others and with other people's expectations of the child. Therefore, the externalizing score consists of the syndromes attention problems and aggressive behaviour. Internalizing and externalizing scores have corresponding T scores, which indicate the extent to which the child's scores are elevated. T scores for internalizing and externalizing can be classified as borderline range (83rd to 90th percentile), clinical range (above the 90th percentile) or normal (less than the 83rd percentile). Finally, a total problem score is determined and has a corresponding T score, which is classified as borderline, clinical or normal, with the same percentile cut-offs as per internalizing and externalizing T scores.

Beery VMI

The Beery VMI Test is composed of drawings of geometric forms arranged in order of increasing difficulty and the individual is asked to copy the drawings (Beery et al., 2004). Using the manual, raw scores are converted into standard scores with a mean of 100 and a standard deviation of 15. A child's visual-motor performance is classified as very high (standard score greater than 129), high (120-129), above average (110-119), average (90-109), below average (80-89), low (70-79) or very low (less than 70).

PPVT-4

The PPVT-4 is an orally administered test consisting of 19 sets of 12 items (228 items), with each item comprising four full-colour pictures on a page (Dunn & Dunn, 2007). The sets are presented in order of increasing difficulty. With each item, the child chooses the picture that most appropriately depicts the meaning of the word that the assessor has spoken. Raw scores are converted into standard scores with a mean of 100 and standard deviation of 15. A child's receptive vocabulary is classified as normal (standard score 85 and above), mildly delayed (70-84) or severely delayed (less than 70).

3.3.4 Procedures

Children were assessed for eligibility to participate in the study after they had completed their four year (corrected age) assessment at the Growth and Development Clinic. To assist with estimating the recruitment period, data from 2006 and 2007 was reviewed. During this timeframe, 139 children of gestational age < 28 weeks and/or a birth weight < 1,000g were born and had attended the Growth and Development Clinic, thus being potentially eligible for inclusion in the study when they were four to four and a half years old (corrected for prematurity). It was anticipated that up to 80 children would fulfil the inclusion criteria during a two year recruitment period.

Prior to this trial, a pilot study had been conducted using the same selection criteria, measures and intervention (Burns et al., 2010). The pilot data demonstrated an average increase of 4 points from baseline to post-intervention on the primary outcome measure, the MABC-2 standard score. This represents approximately a 20% increase in the MABC-2 standard score from baseline. Therefore, assuming a modest increase in score in the standard care group of 0.5 points, and an average increase of 4 points with a common

standard deviation of 4.4, 25 participants per group would be required. The original plan was to recruit more children to take into account the possibility of attrition.

Due to an initial delay in commencing the study and because recruitment was slower than expected, an extension of the study and the recruitment period occurred and the study actually included children born between 2005 to 2008. Additionally, due to these recruitment challenges and the low attrition rate as the study progressed, recruitment ceased after 50 children enrolled in the study.

Parents of eligible children were advised about the study by Growth and Development clinic staff. If parents wished to receive more details, they were contacted by telephone and both an Information sheet (Appendix 1.2) and Consent form (Appendix 1.3) were sent by mail. Once written consent was obtained, children underwent baseline assessment.

Children were then stratified according to their cognitive abilities from the Stanford Binet at their four year assessment with $IQ \leq 85$ / > 85 . Randomisation was performed by the Mater Mothers' Research Centre (MMRC) statistician and this was in the form of variable block randomisation (four per block). Twins were randomised to the same group, due to the nature of the intervention. There were four sets of twins that participated in the study series, two sets were randomised to the intervention group and two sets were randomised to the standard care group. Two of three triplets qualified for the study series and these two children were randomised to the intervention group. There were three children who participated in the study series who had a twin sibling, but their sibling was not eligible to participate. Assignment to group was concealed by using sealed opaque envelopes prepared by a member of MMRC external to the study team. These envelopes were identified by stratification group and consecutively numbered. A member of the research team then allocated these envelopes to children based on the order in which they were booked in for baseline assessment. Baseline assessment included the previously listed tests of motor co-ordination, postural stability and limb strength, functional performance via the GAS (intervention group only and initiated at the commencement of intervention), behaviour, visual-motor skills and literacy skills. Following baseline assessment, parents/guardians were notified which group their child had been assigned to by the physiotherapist leading the intervention.

Children in the intervention group (group one) commenced the intervention program (Appendix 2) within one month of undergoing baseline assessment. Children in the intervention were divided into groups of three to four children per group. Each group attended a six week structured physiotherapy program led by a trained paediatric physiotherapist. The GAS was administered during the first session of the program. Each weekly session was approximately one hour plus 20-30 minutes for explanation of home exercise program and parent discussion. Sessions were progressed in terms of complexity. Intervention was tailored to address a child's specific problems. Parents/guardians and children were also given a weekly goal focused home exercise program. This was progressed in association with the intervention program. The GAS was re-evaluated during the final session of the program. Upon completion of the program, parents/guardians were provided with an informal booklet of general age-appropriate activities to continue with their child over the next 12 months (Appendix 3).

Children in the standard care group (group two) received 'optimal care', which involved best practice advice and, after baseline assessment, an informal booklet of general age-appropriate activities to guide play and outdoor activities during the study period (Appendix 3).

Families of children in both groups were emailed on a two monthly basis throughout the trial, to maintain contact with the families and to provide a forum for families to ask any questions. It was anticipated that regular contact with the families would also assist with retention. Children in both groups were entitled to access other therapies at any time throughout the entirety of the study. The content of these therapies was recorded.

The motor co-ordination and functional performance of all the children was re-assessed within one month of the children in the intervention group completing the program. At one year post baseline assessment, all of the children underwent assessment, which included the same tests performed at baseline, plus the PPVT-4.

Information regarding perinatal and social factors of the children and their parents was provided to the principal investigator at the conclusion of the intervention (the assessors did not receive any of this information).

3.3.5 Data analysis

All analyses were performed using SPSS version 20.0 and 22.0 (IBM Corporation, Armonk, NY, USA, 2011 & 2013). Statistical significance was set at 5% (two-tailed). For normally distributed data, means and standard deviations (SD) were presented, for non-parametric data, medians and inter-quartile ranges (IQRs), and for categorical data, percentages. When comparing between the groups, parametric or non-parametric analyses were used depending on the data distribution and type. Independent and paired comparison *t*-tests were used, as well as repeated measures analyses of variance for continuous normally distributed data. Mann-Whitney *U* tests were used for non-parametric continuous data. For categorical measures, the chi-square or Fisher's exact test was used to determine statistical significance. Pearson's coefficient provided correlations between parametric variables, whilst Spearman's coefficient examined correlations between non-parametric variables. Correlations for non-parametric variables were classified as weak ($\rho=0.2-0.4$), moderate ($\rho=0.4-0.6$) or strong ($\rho>0.7$).

CHAPTER 4

STUDY I Motor performance, postural stability and behaviour of non-disabled extremely preterm or extremely low birth weight children at four to five years of age

Study I explored the characteristics of the whole group of non-disabled extremely preterm or ELBW children at four years of age. It was important to determine baseline performance of the group to enable comparisons to be made between these children and the non-disabled extremely preterm or ELBW population at large. Exploration of performance would also provide a basis for comparing the group of children against themselves over time. The study focused on motor, postural stability and behaviour of the children, and also considered factors that may influence these neurodevelopmental domains.

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4.1 Abstract

Background: Extremely preterm or extremely low birth weight (ELBW) children who are non-disabled and otherwise healthy are at risk of neurodevelopmental impairments. Further understanding of these impairments is needed before commencement of formal education to optimise participation levels at a critical time point for these children.

Aims: To explore motor co-ordination, postural stability, limb strength and behaviour of non-disabled four to five year old children with a history of extreme prematurity or ELBW.

Study design: Prospective-descriptive-cohort-study.

Subjects: 50 children born at less than 28 weeks gestation or who had a birth weight less than 1,000g with minimal/mild motor impairments and no significant neurological/cognitive impairments.

Outcome measures: Movement Assessment Battery for Children second-edition (MABC-2), single leg stance test (SLS), lateral reach test, standing long jump test and Child Behaviour Checklist for preschool children (CBCL).

Results: The mean percentile rank of the extremely preterm or ELBW sample on MABC-2 was 31% (SD 23%). SLS right (mean \pm SD; 4.6 \pm 2.5 seconds) and lateral reach to the right (10.0 \pm 3.9 centimetres) were slightly stronger than SLS left (4.4 \pm 3.3 seconds) and lateral reach left (9.9 \pm 3.5 centimetres). The average for standing long jump was 71.6 centimetres (SD 21.0 centimetres). All participants were classified as 'normal' on CBCL syndrome scale scores, internalizing and externalizing syndrome T scores and total problem T score.

Conclusions: This sample of non-disabled extremely preterm or ELBW children performed in the lower range of normal. These children continue to be at risk of impairments, therefore, ongoing monitoring and tailored intervention may optimise development.

4.2 Introduction

Survival rates amongst extremely low birth weight (ELBW; birthweight <1,000g) infants have improved over time with technological advancements in neonatal intensive care, but since the late 1990s survival rates have plateaued and there remains a need for further improvement in the neurodevelopmental outcomes of these children (Doyle et al., 2011; Saigal & Doyle, 2008). Major disabilities amongst the ELBW or the extremely preterm (born less than 28 weeks gestational age) population have stayed fairly constant or have somewhat decreased over the past decade, but the incidence of more mild problems appears to be rising (Moore et al., 2012; Saigal & Doyle, 2008; Serenius et al., 2013). In association with this increase in neurodevelopmental impairments amongst children born ELBW or extremely preterm who are non-disabled, there has been a realisation that these issues may persist (Burns et al., 2009; Davis et al., 2007; Goyen & Lui, 2009). However, currently, there are minimal, if any, support services available for non-disabled children born ELBW or extremely preterm with mild neurodevelopmental impairments. Children who are non-disabled refers to those children who have no major disability, such as cerebral palsy, and are otherwise healthy and apparently able.

In reference to the International Classification of Functioning, Disability and Health (ICF) framework, health and well being of non-disabled extremely preterm or ELBW children may be affected as a result of disturbances to the natural developmental process (World Health Organization, 2001). Neurodevelopmental impairments may emerge, which may lead to activity limitations and participation restrictions for these children. More specifically, impairments in gross motor function and postural stability are common amongst the non-disabled extremely preterm or ELBW population, as well as behavioural issues (Bos & Roze, 2011; Burns et al., 2004; Burns et al., 2009; Danks, 2010; Goyen & Lui, 2009; Spittle et al., 2009). These impairments may translate into limitations in motor and balance tasks, which may restrict the participation levels of these children in society. Importantly, the contextual factors related to the environment and the individual have the capacity to be modified and may minimise the potential long term sequelae that may unfold amongst this population of children. Therefore, addressing the contextual factors, as well as factors associated with gross motor function, postural stability and behaviour, may provide opportunities for improvement for this group of children.

The impact of neurodevelopmental impairments on the lives of extremely preterm or ELBW children is of particular concern when these children commence formal education, which may start at four and a half years chronological age. It is often considered that non-disabled children who were born 12-16 weeks before term, lack school readiness and this concern is shared by both teachers and parents (Patrianakos-Hoobler et al., 2009; Roberts et al., 2011). Inadequate preparation for school places children at risk of school failure and a cascading series of events that may follow.

Four to five years of age is a critical time point for extremely preterm or ELBW children as their performance at this age is closely linked to their motor performance in their early teenage years (Danks et al., 2012; Sullivan & McGrath, 2003; Sullivan & Msall, 2007). The predictive value of performance at four to five years of age means that those children likely to have ongoing difficulties may be identified early and perhaps linked in with intervention, so that more positive long term outcomes may be reached.

Furthermore, in terms of development, the period between four to six years of age has been referred to as a transitional phase (Shumway-Cook & Woollacott, 1985). This means

that non-disabled extremely preterm or ELBW children at school entry age may be more vulnerable to external influences and have greater capacity to adapt to change at this time.

Studies have emerged exploring the general motor performance of non-disabled extremely preterm or ELBW children at four years of age. Zanudin et al reported that 45.7% of ELBW children in their study had minimal to mild deviations from normal on the Neurosensory Motor Developmental Assessment (NSMDA) at four years corrected age (Zanudin, Burns, et al., 2013). Furthermore, Zwicker et al found that 42% of four to five year old children born less than 1,250g were classified as having developmental co-ordination disorder (DCD) determined by a score on the Movement Assessment Battery for Children (MABC) of less than or equal to the 15th percentile (Zwicker et al., 2013). DCD refers to minor motor difficulties that impact on learning and performance in daily activities, which cannot be explained by the child's age, intellect, or known physical disorder (American Psychiatric Association, 2000).

It has been reported that motor performance and behavioural issues are closely linked amongst extremely preterm or ELBW children (Davis et al., 2007). Davis et al concluded that DCD is more common amongst extremely preterm or ELBW children compared to normal birthweight children and that DCD is associated with poor cognitive and academic performance and a higher prevalence of behavioural problems (Davis et al., 2007). The authors of this study used a stricter cut-off with the MABC to define DCD. One possible explanation for the co-existence of motor and behavioural problems amongst preterm children may be related to abnormalities in the cerebellum and prefrontal cortex which are closely linked (Diamond, 2000).

A range of perinatal and social factors have been linked to outcomes at four years of age amongst non-disabled extremely preterm or ELBW children, including male gender being associated with poorer performance (Marlow et al., 2005; Zwicker et al., 2013). Zwicker et al reported that male gender and lower birth weight were significant predictors of DCD and children with DCD had significantly greater postnatal steroid exposure than those children without motor impairment (Zwicker et al., 2013). In another study by Dewey et al, bronchopulmonary dysplasia, postnatal steroids and increasing gestational age were associated with increased severity of motor impairment in ELBW children at five years of age (children with major disabilities excluded) (Dewey et al., 2011).

Therefore, further investigation to gain a more in depth understanding of the impairments and activity limitations amongst non-disabled extremely preterm or ELBW children at four to five years of age is warranted. The findings will provide useful information to assist in the development of strategies to support better outcomes for this population of children and may enhance participation levels and thus the health and well-being of these individuals.

The current study is part of a larger RCT that will address the role of intervention amongst this population of children. However, the current study, which forms the baseline for the RCT, aimed to explore the motor co-ordination, postural stability, limb strength and behavioural and emotional performance of a sample of non-disabled extremely preterm or ELBW children at four to five years of age. It also investigated the possible relationships between performance measures and perinatal and social factors. Additionally, the study aimed to examine the relationship between gender and perinatal and social factors and the relationship between gender and performance.

4.3 Methods

4.3.1 Inclusion criteria

Children were born between May 2005 and November 2008. They had a birth weight of less than 1,000g or had a gestational age of less than 28 weeks (extreme prematurity) and were managed in the Neonatal Intensive Care Unit at the Mater Mothers' Hospital, Brisbane, Australia. Therefore, the study population included children that were ELBW and/or extremely preterm, but for conciseness, this population will hereafter be referred to as ELBW. Only children who lived within one hour travel of the testing centre were invited to participate. Children were aged between four to four and a half years corrected for prematurity when commencing involvement in the study and had not started formal education (preparatory year of schooling). Included children had attended their four year (corrected age) Growth and Development clinic follow-up assessment and had a score from the NSMDA of 9 to ≤ 12 and an IQ of > 70 on the Stanford Binet test.

The NSMDA is a criterion-referenced assessment tool of gross and fine motor performance, postural development, neurological characteristics and the motor responses to sensory input (Burns, 2014). A score of 9 to ≤ 12 indicates minimal to mild deviation from age expected motor performance. NSMDA score at four years corrected age is of particular relevance as it has been shown to independently predict motor co-ordination at 11-13 years of age with a positive predictive value of 87% (Danks et al., 2012).

The Stanford Binet Test is a standardised test that assesses intelligence and cognitive abilities and is suitable for ages two to 85 plus years (Roid, 2003). A score of <70 corresponds to an IQ classification of delayed development.

4.3.2 Exclusion criteria

Children with significant congenital anomalies, diagnosed neurological impairments including cerebral palsy, a visual impairment not corrected by wearing corrective lenses, or a hearing impairment not corrected by aids, were excluded. Additionally, due to practical implications for the larger study, children were not eligible to participate if their parents/carers did not speak English or if their family identified that they could not commit to the study attendance requirements.

4.3.4 Procedures

Eligibility to participate in the study was determined after completion of the four year (corrected age) assessment at the Growth and Development clinic. Parents of eligible children were then contacted to find out if they wished to receive further information and consent forms. Once written consent was obtained, children underwent baseline assessment by assessors who had no background information about the children. Assessors were trained in a set testing protocol. Each assessment took approximately one hour and occurred at the Mater Children's Hospital, Brisbane.

Information in relation to perinatal and social history of eligible children was retrieved from medical records.

The Mater Health Services Human Research Ethics Committee and The Medical Research Ethics Committee of the University of Queensland granted approval for the study.

4.3.4 Assessment measures

Movement Assessment Battery for Children second-edition (MABC-2)

Motor performance was assessed using the MABC-2 (Henderson et al., 2007). It is an internationally recognised standardised test of motor co-ordination for children and adolescents (Brown & Lalor, 2009) and has applicability to children with more mild motor impairments associated with prematurity (Brown & Lalor, 2009). Individual component scores of the MABC-2 have been shown to be reliable and have acceptable correlation with each other and the total test score (Henderson et al., 2007). Therefore, it is meaningful to consider each of the three subsections independently, as well as looking at the total standard score. A percentile rank above the 15th percentile on the MABC-2 corresponds to normal motor skills, whereas less than or equal to the 15th percentile is indicative of potential motor problems (at risk or impaired).

Measures of postural stability

Timed single leg stance and lateral reach test were used to measure functional postural control and balance. Although few measurements of postural stability in children are available that are reliable and valid (Westcott et al., 1997) and norms for these tests are lacking, the above mentioned tests are functional, commonly applied in the clinical setting and have been used to varying degrees in children with developmental co-ordination disorder (DCD) and cerebral palsy, as well as with ELBW children (Auld & Johnston, 2008; Burns et al., 2010; Burns et al., 2009; Johnston et al., 2004). Additionally, the SLS test has a standard proforma, and has been shown to have excellent test-retest reliability in typically developing and in hearing impaired children (De Kegel et al., 2011). Furthermore, the lateral reach test has been shown to be a reliable and valid measure of medio-lateral postural stability in adults (Brauer et al., 1999), as well as in children, when incorporated into the Paediatric Reach Test (PRT) (Bartlett & Birmingham, 2003).

For both the SLS test and lateral reach test there was a set testing protocol with standard instructions. Children were tested barefoot and were given three trials per side of the body with best performance recorded.

Single Leg Stance (SLS) test (seconds)

Timing commenced when the child lifted the nominated leg. The free foot was not permitted to touch the other leg or the floor. Eyes remained open. Timing ceased when the nominated leg touched the floor or when the testing criteria were no longer satisfied.

Lateral Reach test (centimetres)

The child stood in front of a wall with feet shoulder width apart and with the nominated arm raised to 90 degrees of abduction. The child then reached as far sideways as possible whilst maintaining a fixed base of support. The child was not allowed to lean against the wall. The difference between arm's length and maximal lateral reach of the finger tip of the 3rd finger was recorded (Bartlett & Birmingham, 2003).

Functional measures of Limb Strength

Standing Long Jump test (centimetres)

The standing long jump was used to assess impairment, specifically, functional lower limb strength and control. There is evidence supporting its reliability as a measure of explosive strength amongst four and five year old children (Oja & Jürimäe, 1997). A set testing protocol was used with standard instructions. Children were tested barefoot and were given three trials with best performance recorded. The child stood with their toes behind a marked takeoff line, crouched and jumped forwards as far as possible. The child had to land two feet together. The horizontal distance jumped was measured from the takeoff line to the point of the child's body that landed closest to the starting point (Oja & Jürimäe, 1997).

Child Behaviour Checklist for Preschool Children (CBCL)

The CBCL/1 ½ -5 was used to determine the frequency of behavioural and emotional problems (Achenbach & Resorla, 2000). It is a standardised test completed by parents and is normed on national samples of children from the United States of America. There is evidence to support the validity and reliability of the problem scales of this test (Achenbach & Resorla, 2000).

The CBCL/1 ½ - 5 requests demographic details and rating of 99 problem items on a three point scale. Problem items are converted into syndrome scale scores which can be classified as borderline clinical range (93rd to 97th percentile), clinical concern (above the 97th percentile) or normal (less than the 93rd percentile). Each syndrome scale score has a corresponding T score, which are standard scores that have a consistent meaning for each scale. Additionally, scoring involves calculating an internalizing and externalizing score which are scores based on groupings of syndromes. Internalizing and externalizing scores have corresponding T scores too, which indicate the extent to which the child's scores are elevated. T scores for internalizing and externalizing can be classified as borderline range (83rd to 90th percentile), clinical range (above the 90th percentile) or normal (less than the 83rd percentile). Finally, a total problem score is determined and has a corresponding T score, which is classified as borderline, clinical or normal, with the same percentile cut-offs as per internalizing and externalizing T scores.

4.3.5 Statistical analysis

Statistical analysis was performed using SPSS version 20.0 (IBM Corporation, Armonk, NY, USA, 2011). Statistical significance was set at 5% (two-tailed). Differences between the group of children tested (participants) and the group of children eligible for the study who did not participate (non-participants) were examined. For normally distributed data, means and standard deviations (SD) are presented, for non-parametric data, medians and inter-quartile ranges (IQRs), and for categorical data, percentages. When comparing between the groups, parametric or non-parametric analyses were used depending on the data distribution and type. Independent *t*-tests or analyses of variance were used for continuous normally distributed data and Mann-Whitney *U* tests for non-parametric continuous data. For categorical measures, the chi-square or Fisher's exact test was used to determine statistical significance.

4.4 Results

4.4.1 The ELBW cohort

Seventy-nine children met inclusion criteria of which 50 children completed testing. Of the 29 who did not participate in the study, two had recently commenced formal education when invited to participate in the study and one child was about to move a considerable distance from the testing site when contacted. The remaining 26 children either declined or were unable to participate within the required timeframe.

****Further information not published in the study****

In terms of gender distribution of the 79 children eligible for the study, 46 were males and 33 were females (Table 4.1). Out of the 50 children who completed testing, 26 were males and 24 were females.

Differences between participants and non-participants – perinatal factors, social factors, motor performance

The perinatal and social characteristics of the participants (study children) were compared with those of the cohort eligible for the study but who did not participate (non-participants) (Table 4.1). There were no significant differences between the groups on any of these variables. However, there was a trend towards a difference between the groups with respect to being discharged home on oxygen, with 36% of non-participants home on oxygen as opposed to 16% of the study children ($p = 0.053$). In discussing perinatal and social factors, it is important to note here that for certain factors, comparisons between groups were made based on sub-categories within these factors, such as comparing periventricular haemorrhage based on grade. In terms of NSMDA total score, no differences were found between the groups ($p = 0.221$) (Table 4.1).

Table 4.1 - Comparison of perinatal and social characteristics of the study children (participants) and eligible children not included in the study (non-participants)

Factor	Whole group – participants and non-participants (n=79)	Participants (n=50)	Non-participants (n=29)	P
Maternal age (years), mean (SD)	31.2 (5.2)	31.2 (4.9)	31.1 (5.9)	0.934
Private health insurance, n (%)	44 (56)	30 (60)	14 (48)	0.312
Antepartum haemorrhage, n (%)	9 (13)	5 (12)	4 (15)	0.388
Antenatal steroids, n (%)	77 (98)	48 (96)	29 (100)	0.552
Multiple births, n (%)	20 (26)	13 (26)	7 (25)	0.551
Caesarean section, n (%)	57 (72)	35 (70)	22 (76)	0.680
Gestation (weeks), mean (SD)	26.7 (1.9)	27.0 (2.0)	26.5 (1.6)	0.371
Birthweight (g), mean (SD)	842.5 (167.8)	838.8 (174.8)	848.9 (157.9)	0.798
Male gender, n (%)	46 (58)	26 (52)	20 (69)	0.141
Apgar at 5 mins < 7, n (%)	8 (10)	5 (10)	3 (10)	0.551
RDS, n (%)	70 (90)	44 (90)	26 (90)	0.984
Chronic neonatal lung disease, n (%)	28 (35)	15 (30)	13 (45)	0.184
Late onset infection, n (%)	16 (21)	9 (18)	7 (25)	0.463
Necrotising enterocolitis, n (%)	4 (5)	2 (4)	2 (7)	0.794 ^a
Periventricular haemorrhage, n (%)	10 (13)	6 (12)	4 (14)	0.999 ^a
Periventricular leukomalacia, n (%)	1 (1)	1 (2)	0 (0)	0.999 ^a
Home on O2, n (%)	18 (23)	8 (16)	10 (36)	0.053
Motor performance				
NSMDA, mean (SD)	10.6 (1.1)	10.7 (1.1)	10.4 (1.2)	0.221

^a Fisher's exact test

4.4.2 The ELBW sample

Motor co-ordination

To examine the motor co-ordination of the study children, further analyses were conducted (Table 4.2). The mean age corrected for prematurity at which time children underwent testing, was 50 months (SD 2.6 months). In terms of performance on the MABC-2, the mean percentile rank of the group was 31% (SD 23%). Although this translates to 'normal' motor skills, when looking at the distribution of the group on this variable in greater detail, 15 children (30%) actually scored below the 15th percentile, with two of these children (4%) scoring less than the fifth percentile. A one-sample proportion test was used to compare the sample proportion of 30% of children with a theoretical proportion of 15% (percent expected to be at risk on the MABC-2), which showed a

significant difference between these proportions ($p = 0.003$). Mean percentiles for the three subsections of the MABC-2 are shown in Table 4.2.

Table 4.2 - Motor co-ordination, postural stability and limb strength of participants (n=50)

Item	Mean (SD)	Range	%ile Mean (SD)
Manual dexterity (SS)	8.1 (2.4)	5-13	31 (25)
Aiming & catching (SS)	9.4 (2.7)	2-19	44 (26)
Balance (SS)	8.1 (2.2)	3-17	30 (21)
Total MABC-2 (SS)	7.9 (2.4)	3-15	31 (23)
SLS right (seconds)	4.6 (2.5)	1-24	
Lateral reach right (cm)	10.0 (3.9)	5-21	
SLS left (seconds)	4.4 (3.3)	2-15	
Lateral reach left (cm)	9.9 (3.5)	4-18	
Standing long jump (cm)	71.6 (21.0)	35.2-120	

Relationship between motor co-ordination groups and postural stability/limb strength, CBCL, and perinatal/social factors

The study children were further analysed in accordance with the DCD definition and were therefore divided into two groups: MABC-2 percentile rank greater than the 15th percentile versus MABC-2 percentile rank equal to or less than the 15th percentile (Table 4.3). Children in the latter group all performed significantly poorer on SLS left and right ($p = 0.002$ and $p = 0.030$ respectively), lateral reach right ($p = 0.044$) and standing long jump ($p = 0.002$) compared to children in the MABC-2 group with a percentile rank greater than the 15th percentile. There were no significant differences between the MABC-2 groups on the CBCL scores (data not shown).

There were no significant differences between MABC-2 groups when comparing perinatal and social factors (data not shown).

Table 4.3 - Relationship between motor co-ordination groups and functional measures of postural stability and limb strength (n=50) - MABC-2 > 15th percentile group vs. MABC-2 ≤ 15TH percentile group

Functional measures	MABC-2 > 15 th % group (n=35)	MABC-2 ≤ 15 TH % group (n=15)	<i>p</i>
<i>Measures of postural stability</i>			
SLS right (seconds), mean (SD)	5.3 (2.5)	3.0 (1.6)	0.002
SLS left (seconds), mean (SD)	5.0 (3.7)	2.8 (1.3)	0.030
Lateral reach right (cm), mean (SD)	10.7 (3.8)	8.3 (3.7)	0.044
Lateral reach left (cm), mean (SD)	10.4 (3.6)	8.7 (3.1)	0.121
<i>Functional measures of limb strength</i>			
Standing long jump (cm), mean (SD)	77.3 (19.9)	58.2 (17.3)	0.002

Postural stability and limb strength

When considering the postural stability of the study children in a functional context, SLS right and lateral reach to the right were slightly stronger than their counterpart measures on the left side (Table 4.2), but not significantly.

Standing long jump, indicative of strength and control of the lower limbs, showed a degree of variability amongst the study children, with mean, SD and range shown in Table 4.2.

CBCL

In terms of syndrome scale scores, internalizing and externalizing syndrome T scores and total problem T score, all study children were classified as ‘normal’ according to the

manual's criteria (Table 4.4). Upon closer examination of individual performances on the CBCL, between five (11%) and seven (15%) children had a score that corresponded to the clinical range, and therefore is of concern, on all T scores (internalizing, externalizing and total problem). In regards to individual performances on the CBCL scale scores, some children had scores in the clinical range, including one for somatic complaints, three for withdrawn, four for sleep problems, five for attention problems, and two for aggressive behaviour.

Table 4.4 - CBCL T score results of participants (n=46)

CBCL score	Mean	SD	Group performance overall – normal/borderline/clinical range (concern)	Individual – number abnormal (clinical range), n (%)
Internalizing	51.1	10.6	Normal	7 (15)
Externalizing	48.6	12.0	Normal	5 (11)
Total problems	50.0	11.1	Normal	6 (13)

Relationship between gender and performance

Gender had no significant impact on motor co-ordination, postural stability or limb strength. However, there was a significant effect of gender on the CBCL syndrome scale score of withdrawn ($p = 0.05$), CBCL syndrome scale score of sleep problems ($p = 0.031$), CBCL internalizing syndrome T score ($p = 0.028$), and CBCL total problem T score ($p = 0.013$). On all of these mentioned CBCL scores, males had a higher mean score than females and therefore had more behavioural issues in these areas. Appendix 4 provides further details regarding gender effect on participants for CBCL scores.

4.5 Discussion

The non-disabled ELBW children included in this study had an overall performance in the lower range of normal, particularly in reference to motor co-ordination, with scores well below the 50th percentile. However, the performance of the study children represents a better outcome than that reported elsewhere at four to five years of age (Zwicker et al., 2013).

When considering the ELBW cohort at large, their perinatal and social characteristics appear to be fairly representative of trends demonstrated in current literature, including male gender accounting for a higher proportion of the cohort at large (Chow, 2013; Zanudin, Burns, et al., 2013). Although, in terms of the study children, there was a fairly equal distribution of males and females.

The MABC-2 scores of the study children were higher than anticipated, especially considering eligibility criteria included an NSMDA score that indicated that the children demonstrated minimal to mild deviation from normal. However, it is important to note that the NSMDA provides information about a child's motor development and related systems and does not just examine motor performance in isolation. An association between the NSMDA and the MABC in term born children aged 6 years has been reported (Foulder-Hughes & Cooke, 2003) with 76% agreement. The NSMDA identified more children with minimal/mild problems than the MABC which is consistent with findings in the present study (note the original MABC was used rather than the MABC-2 as in this study). Also, children may have performed better on the MABC-2 than the NSMDA as children are not required to perform in a sustained or consistent manner in the MABC-2 and may score highly with a 'one off' performance (Bosanquet et al., 2013).

The mean percentile rank of the children on the MABC-2 was 31%, corresponding to a 'normal' outcome. This higher than expected result may be due to the age of the children as other studies report that the prevalence of motor co-ordination impairments in non-disabled ELBW children increases with age (Burns et al., 2009; Goyen & Lui, 2002). Therefore, in time, motor deficits may become more apparent amongst the study children. In addition, the MABC-2 test itself may have contributed to the current study findings. The MABC-2 has received criticism surrounding the variability of studies reported in the test

manual, particularly in relation to quality, reliability and validity (Brown & Lalor, 2009). Therefore, some caution is required when interpreting the results. Another reason for the study children performing better than expected on their motor co-ordination testing may be related to the children's scores being calculated based on their corrected age. Also, the study children may have performed better than expected because the non-participants had an almost significantly higher requirement for being discharged home on oxygen and chronic lung disease has been associated with poorer motor performance (Zanudin, Burns, et al., 2013). Finally, other factors related to the early management of the study children may have contributed to them having a mean percentile rank of 31% on the MABC-2. For example, perhaps children in this study had a history of better postnatal weight gain compared to ELBW children in other studies. An exploration of the rate of weight gain through childhood and whether this relates to motor outcomes may be worth considering in future studies.

When interpreting MABC-2 results, it is important to explore beyond mean percentile rank. When looking at individual performances, 30% of children scored below the 15th percentile. In terms of the three subsections of the MABC-2, the mean percentile for aiming and catching of the study children was higher (44%) than that for manual dexterity (31%) and balance (30%). These findings are consistent with the study by Zwicker et al, which found that children aged four to five years with a history of very low birth weight (VLBW; birthweight <1,250g), performed most poorly in the balance subsection, followed by manual dexterity (Zwicker et al., 2013). The authors suggested that balance and fine motor difficulties may be 'early' indicators of DCD. On the other hand, perhaps the children in the current study performed better on the aiming and catching subsection because this activity is a popular activity in this age group and therefore their skills in this subsection were more developed.

Upon closer examination of the study children according to DCD classification, the finding that those children in the group who met this criteria (MABC-2 percentile rank equal to or less than the 15th percentile) had poorer postural stability compared to those children in the group who did not meet this criteria, is noteworthy. Reduced postural stability will impact on the efficiency of performance and therefore highlights the need to consider quality of performance in DCD, not just ability. The co-existence of altered postural muscle activity and DCD has been identified in previous studies (Johnston et al., 2002).

Perhaps then, ELBW children are not only predisposed to having poorer postural stability compared to their term equivalent peers at four to five years of age (Lorefice et al., 2012a), but within the ELBW population, if they meet the DCD criteria, this impairment is even more pronounced.

In further discussing the study children according to MABC-2 group, there were also differences between the present study and previous studies. In contrast to other studies which have found preterm children with DCD to have a higher prevalence of behavioural issues, this was not the case in the current study (Davis et al., 2007; Foulder-Hughes & Cooke, 2003). One possible explanation for this disparity in findings may be due to the children in previous studies being older than the children included in this study. Additionally, in the current study, there were no significant differences between MABC-2 groups when comparing perinatal and social factors. However, in other studies, perinatal and social factors have been linked to DCD and severity of motor impairment (Dewey et al., 2011; Zwicker et al., 2013).

In regards to SLS and lateral reach, the study children demonstrated that they were somewhat stronger on their right side, and accompanying this, there was a wider range of results on the right side compared to the left side. The reason for the right side dominance may be related to hand preference, with a greater number of participants being right-handed. As previously mentioned, norms for postural stability are lacking. In a study by Largo et al, the average for SLS amongst typically developing five year olds was approximately seven to eight seconds compared to approximately four seconds in the current study. It is important to note that the children in the current study were slightly younger in terms of their corrected age and that the SLS testing procedure in the Largo et al study differed a little (Largo et al., 2001).

When looking more closely at standing long jump, the mean for the study children was 71.6cm, but there was a wide range in results (35.2cm – 120.0cm). This mean is well below means reported for typically developing children (Oja & Jürimäe, 1997). In a study by Oja et al, the mean at four years was found to be 88.2cm for boys and 84.7cm for girls and at five years to be 105.4cm for boys and 100.1cm for girls (Oja & Jürimäe, 1997). When the genders are combined, at four years, this is equivalent to an overall mean of 86.5cm and at five years, an overall mean of 102.8cm. In addition, children with MABC-2

performances equal to or below the 15th percentile performed more poorly on standing long jump than those children with MABC-2 scores above the 15th percentile. Therefore, those children in the 'at risk' category according to their motor performance, also demonstrated impairments in strength and control, which are likely to add to their activity limitations and perhaps contribute to participation restrictions.

Interpretation of the CBCL results indicate that overall, the study children performed well within the normal range. It may be that behavioural and emotional problems become more apparent once these children commence formal education and perhaps with feedback from an external source, such as a teacher. There is evidence in the literature supporting this idea of behavioural problems becoming more evident after school entry (Hayes & Sharif, 2009). Being able to identify specific children demonstrating behavioural issues (up to 15% in this study), would facilitate timely intervention, possibly averting the further development of behavioural difficulties reported at later ages in other studies.

Furthermore, in the current study, gender was found to be significantly related to some CBCL scores, with males performing more poorly. This finding links to other studies which have demonstrated that males are at greater risk of impairment than females (Marlow et al., 2005; Zwicker et al., 2013).

In regards to strengths of this study, the finding that the children performed at a higher level than expected, adds depth to current research as it challenges what has generally been found amongst this population of children. Additionally, the current study not only used the more recently developed MABC-2, but included a range of outcome measures to provide more detailed information. As there were no significant differences between the study children and non-participants in this study, the results can be regarded as representative of an anticipated larger group. Furthermore, the current study had rigorous inclusion criteria, therefore the results are specific to ELBW children and not simply low birth weight children at large.

In terms of limitations of the present study, the tight inclusion criteria meant a relatively small sample size, which may have implications for generalisation. Also, there was no term-equivalent control group, which would have been useful for comparison purposes and to ensure blinding of assessors. Additionally, whilst outcome measures of the study

were fairly robust and objective, there is a lack of qualitative information provided by these measures. Similarly, use of the 'best single performance' advantages those with motor deficit, who may be able to produce one acceptable response, but may not be able to reproduce this level of performance. Further qualitative measures of performance may have provided more insight into the children's strengths and weaknesses. Other information that would have been useful to consider in terms of affect on performance would have been birth weight for gestational age, pattern of weight gain since birth, weight of the children at the time of testing and postnatal morbidity.

4.6. Conclusion

The results indicate that on the whole, the non-disabled ELBW children in this study have low average motor co-ordination, postural stability, limb strength and behavioural and emotional characteristics at four to five years of age. It seems that with time, these particular children are at risk of problems emerging (Danks et al., 2012). Therefore, ongoing screening of these children is essential. Those children who performed equal to or below the 15th percentile on the MABC-2 also had poorer postural stability and lower limb strength and control than those children with better motor performance, providing directions for future intervention. A proactive approach should be adopted, especially considering up to 15% of the children in the current study were identified as having behavioural issues already. Engagement of non-disabled ELBW children in tailored intervention programs may facilitate optimal development, maintain adequate motor performance, and minimise the development of impairments.

4.7 Additional information

Null hypothesis I associated with study I should be accepted. The non-disabled extremely preterm or ELBW children group performed, at large, in the normal range, although it was at the lower end of normal range.

CHAPTER 5

STUDY II Group-based physiotherapy intervention to improve motor co-ordination, postural stability and limb strength in non-disabled ELBW children: a randomised controlled trial

After establishing the baseline characteristics of the non-disabled extremely preterm or ELBW group, the next step was to explore the short term effect of group-based intervention compared to best practice advice. This was achieved via a randomised controlled trial. The focus of the short term changes was on motor and postural outcomes.

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Brown, L., Burns, Y. R., Watter, P., Gibbons, K. S., Gray, P. H. Group-based physiotherapy intervention to improve motor co-ordination, postural stability and limb strength in non-disabled ELBW children: a randomised controlled trial.

5.1 Abstract

Aim: To determine the effect of group-based physiotherapy intervention compared to standard care on motor co-ordination, postural stability and lower limb strength in non-disabled extremely preterm/extremely low birth weight children.

Methods and Procedures: 50 four-year-old children, born <28 weeks gestation or with birth weight <1,000g with minimal/mild motor impairment, were randomly allocated to six weeks of group-based intervention (n=24) or standard care (n=26). All children received a booklet of general age-appropriate activities. Assessment occurred at baseline and then all children were re-assessed within one month of completion of the intervention using Movement Assessment Battery for Children-2, single leg stance, lateral reach and standing long jump.

Outcomes and Results: 24 intervention children (mean corrected age 49.6 months, SD 2.4 months; 10 males) and 24 standard care children (mean corrected age 50.1 months, SD 2.6 months; 14 males) completed the study. While both groups showed significant improvement over time (both $p=0.001$), there were no between group differences over

time. Within group comparison demonstrated that both groups improved on all measures to varying degrees.

Conclusions and Implications: Both groups improved over time. Compliance with best practice advice and group-based physiotherapy intervention lead to positive short term results.

5.2 Introduction

Non-disabled extremely preterm (born < 28 weeks gestational age) or extremely low birth weight (ELBW; birthweight < 1,000g) children commonly present with neurodevelopmental impairments in gross motor function and postural stability (Burns et al., 2009; Goyen & Lui, 2009). In alignment with the International Classification of Functioning, Disability and Health (ICF) framework, these impairments may translate into limitations in motor and balance performance, which may restrict the participation levels of these children in everyday life (World Health Organization, 2001). The impact of these impairments is of particular significance when these children commence formal education.

Although these children have no major impairments and are otherwise healthy and able-bodied, teachers and parents often report that these children lack school readiness (Roberts et al., 2011). Inadequate preparation for school may lead to school difficulties and subsequent problems, including school failure and participation restrictions (Woodward et al., 2009).

Performance at four years has been reported to be predictive of performance in teenage years amongst ELBW children (Danks et al., 2012). If school difficulties emerge at four years of age, these problems may persist and reinforces their potential cascading effect. Furthermore, in terms of development, four to six years of age has been referred to as a transitional phase (Shumway-Cook & Woollacott, 1985), which means that extremely preterm or ELBW children may respond more readily to intervention during this time.

Therefore, intervention amongst non-disabled extremely preterm or ELBW children who have mild neurodevelopmental impairments requires consideration, especially at four years. Currently, services are lacking for these children who are often overlooked due to

their apparent overall ability and minimal nature of their difficulties (Burns et al., 2004). Various models of early interventions have been established amongst the extremely preterm or ELBW population with mixed degrees of success (Spittle et al., 2015). Group-based intervention has been shown to be effective amongst older children of differing populations, including children with cerebral palsy (Auld & Johnston, 2014) and children with developmental co-ordination disorder (DCD) (Pless et al., 2000; Watter & Bullock, 1989). DCD refers to minor motor difficulties that impact on learning and performance in daily activities, which cannot be explained by the child's age, intellect, or known physical disorder (American Psychiatric Association, 2000). Non-disabled ELBW children with mild neurodevelopmental impairments are commonly identified as having DCD. Further evidence supporting group-based physiotherapy was found in a pilot study exploring the benefits of intervention amongst four year old children born extremely preterm or with ELBW and mild neurodevelopmental impairments (personal communication).

The pilot study findings provided the foundations for the randomised controlled trial (RCT) presented in this paper. This RCT is part of a larger study, in which the initial phase involved exploring the performance of a cohort of non-disabled extremely preterm or ELBW children at four years of age (Brown et al., 2015). The current RCT aimed to elucidate the short term effect of a brief group-based physiotherapy intervention program compared to standard care on motor co-ordination, postural stability and lower limb strength amongst these children.

5.3 Methods

5.3.1 Participants

The characteristics of the children in this RCT have already been described (Brown et al., 2015). In summary, children were born between May 2005 and November 2008. They had a birth weight of < 1,000g or a gestational age of < 28 weeks (extreme prematurity) and were managed in the Neonatal Intensive Care Unit at the Mater Mothers' Hospital, Brisbane, Australia. For conciseness, the children in this study will hereafter be referred to as ELBW. Eligible children lived within one hour travel of the testing centre. Children were four to four and a half years corrected for prematurity when commencing involvement

in the study and had not started formal education. Included children had attended the Mater Mothers' Hospital Growth and Development clinic for follow-up assessment at four years (corrected age) and had a score from the Neurosensory Motor Developmental Assessment (NSMDA) (Burns et al., 1989) of 9 to ≤ 12 (minimal to mild deviation from normal) and an IQ of > 70 (<70 corresponds to delayed development) on the Stanford-Binet Intelligence Scales (Roid, 2003).

Children were excluded if they had significant congenital anomalies, diagnosed neurological impairments, a visual impairment not corrected by corrective lenses, or a hearing impairment not corrected by aids. Children were excluded if their parents/guardians did not speak English or if their family could not commit to the study attendance requirements.

5.3.2 Procedures

Children were assessed for eligibility after completion of their four year assessment at the Growth and Development clinic. Information in relation to perinatal and social history of eligible children was retrieved from medical records to explore the potential influence of these factors on outcomes. Parents of eligible children were advised about the study by clinic staff. If parents wished to receive more details, Information and Consent forms were sent by mail. Once written consent was obtained, children underwent baseline assessment by a team of paediatric physiotherapists who had no background information about the children, except date of birth and expected date of birth. Assessors were trained in a set testing protocol that involved a consistent order for the various assessments performed. The assessors had no involvement in the intervention or standard care of the children and were blinded to group allocation. Each assessment took approximately one hour and occurred at the Mater Children's Hospital, Brisbane.

Children were stratified according to their cognitive abilities from the Stanford Binet at their four year assessment with $\text{IQ} \leq 85$ / > 85 . Randomisation was performed by the Mater Mothers' Research Centre (MMRC) statistician and this was in the form of variable block randomisation (four per block). Twins were randomised to the same group, due to the nature of the intervention. Assignment to group was concealed by using sealed opaque envelopes prepared by a member of MMRC external to the study team. These

envelopes were identified by stratification group and consecutively numbered. A member of the research team then allocated these envelopes to children based on the order in which they were booked in for baseline assessment. Following baseline assessment, parents/guardians were notified which group their child had been assigned to by the physiotherapist leading the intervention.

Intervention was group-based and combined traditional physiotherapy and task-oriented approaches. Traditional physiotherapy involves training an individual in essential age-specific gross and fine motors skills, as well as the fundamental motor abilities necessary to perform those skills. Task-oriented approach emphasises motor performance and incorporates cognitive approaches with attention directed towards specific aspects of a motor skill. Both approaches have been shown to be effective in teaching motor skills in children with DCD (Smits-Engelsman et al., 2013).

Children in the intervention group commenced the program within one month of undergoing baseline assessment and groups consisted of three to four children. Each group attended a six week structured physiotherapy program (Table 5.1) led by a trained paediatric physiotherapist. Intervention was tailored to each child's specific problems. The intervention program included activities specifically addressing postural control and balance. It also included some sensori-motor and upper girdle strength components associated with postural control. The weekly sessions were approximately one hour plus 20-30 minutes for explanation of home exercise program and parent discussion. Home program was progressed in association with the intervention program in terms of complexity. The standard care group received 'optimal care' which consisted of best practice advice and a booklet of general age-appropriate activities which included ideas for imaginative and exploratory play, counting objects, drawing and playground gross motor games. Children in the intervention group also received this booklet. Communication to parents about the activity booklet was similar for both groups. Children in both groups were not prevented from receiving other therapies. Two children in the intervention group were attending occupational therapy at the time of their involvement in the study. All children were re-assessed on the tests they underwent at baseline assessment within one month of the children in the intervention group completing the program.

Table 5.1 - Summary of group-based physiotherapy intervention program

Program components	Approximate time (minutes)	Examples of activities
Warm-up	5	Walking/running drills (e.g. run-stop-run) Action games Marching exercises
Postural control/core stability	10	Long-sit - perform task involving bilateral arm reach Sit on chair with feet free - perform bilateral arm task (e.g. ball throw) Four-point kneel - static then dynamic exercises Crook lying - static then dynamic exercises Stand - perform bilateral reach task
Paired activities	5	Sit and roll ball to partner Mirror action games Hand clapping games - simple patterns then cross patterns
Upper limb strength	10	Commando – elbow creep/crawl activities Wall press-ups <i>Theraband</i> exercises and tug-o-war Crab walks
Balance (static and dynamic)	10	Single leg stand activities (e.g. kick ball) Balance board exercises – perform in sitting Balance beam circuit Step-up backwards (e.g. use obstacle course with blocks) Heel-toe exercises (e.g. along a line, balance beam)
Sensori-motor	10	Eye tracking tasks Position awareness games (e.g. copy limb and hand positions) Vestibular activity using blind-fold Tactile perception (eg. find shapes in boxes of varying textures)
Fine motor	5-10	Drawing activity (e.g. copy letters, draw family, write name)
Warm-down	5	Rocket take-off game involving single leg stand Elephant walks Indoor T-ball Running games (e.g. circles and figures of 8)
Individual	10	Activities specific to each child
Parent time/discussion	10	Parent-expected goals Behaviour (e.g. increasing attention) Progression ideas Questions/feedback
Home program	10	Activities for home that relate to addressing specific goals including: improving postural stability, improving weight shift/balance, improving position awareness of body parts, increasing attention to tasks, child specific

Note: Some activities were conducted simultaneously eg. warm-down and parent/time

The Mater Health Services Human Research Ethics Committee and The Medical Research Ethics Committee of the University of Queensland granted approval for the study. This RCT was registered with the Australian New Zealand Clinical Trials Registry (ACTRN12613000950763).

5.3.3 Measurements

Primary Outcome

Movement Assessment Battery for Children second-edition (MABC-2)

Motor performance was assessed using the MABC-2 (Henderson et al., 2007) which is a standardised test of motor co-ordination (Brown & Lalor, 2009) and has applicability to children with mild motor impairments associated with prematurity (Brown & Lalor, 2009). There are three components: manual dexterity, aiming and catching, and balance. Individual component scores have been shown to be reliable and have acceptable correlation with each other and the total test score (Henderson et al., 2007). Therefore, each of the three subsections can be considered independently, as well as considering the total standard score. A percentile rank $\leq 15^{\text{th}}$ percentile is indicative of potential motor problems or DCD (at risk or impaired). The MABC-2 percentiles are determined according to the specific age band that the child falls within. The manual states that regardless of which age band the child is assessed in, the results provide a standard score and a percentile that are comparable to norms, so it should not matter if a child is assessed in one age band and then re-assessed in another. However, in this study, due to the short intervention period and to allow more accurate comparison of each child's individual changes between baseline and re-assessment, the child's age band at baseline was used again at re-assessment.

Secondary Outcomes

Measures of postural stability

Timed single leg stance (SLS) and lateral reach test were used to measure functional postural control and balance. There are few reliable and valid measurements of postural stability in children (Westcott et al., 1997) and norms for these tests are lacking, but the above tests are functional, common in the clinical setting and have been used in children with DCD and cerebral palsy, as well as with ELBW children (Auld & Johnston, 2014; Burns et al., 2009). Additionally, SLS test has a standard proforma, and has excellent

test-retest reliability in typically developing and in hearing impaired children (De Kegel et al., 2011). Furthermore, lateral reach test has been shown to be a reliable and valid measure in children when incorporated into the Paediatric Reach Test (Bartlett & Birmingham, 2003).

For the SLS, lateral reach and standing long jump tests, there was a set testing protocol with standard instructions. Children were tested barefoot and were given three trials per side of the body with best performance recorded.

Single Leg Stance (SLS) test (seconds)

Timing commenced when the child lifted the nominated leg. The free foot was not permitted to touch the other leg/floor. Eyes remained open. Timing ceased when the nominated leg touched the floor or when the testing criteria were no longer satisfied.

Lateral Reach test (centimetres)

The child was required to stand in front of a wall with feet shoulder width apart and with the nominated arm raised to 90 degrees of abduction. The child then reached as far sideways as possible whilst maintaining balance and a fixed base of support. The child was not allowed to lean against the wall. The distance reached was measured as the difference between arm's length (at 90 degrees of abduction) and maximal lateral reach of the finger tip of the third finger (Bartlett & Birmingham, 2003).

Functional measures of Limb Strength

Standing Long Jump test (centimetres)

The standing long jump was used to assess functional lower limb strength and control. Adequate postural control is required to perform this task. Standing long jump was selected over the seated throw as it would relate more to activities such as SLS and motor performance. There is evidence supporting its reliability as a measure of explosive strength amongst four and five year old children (Oja & Jürimäe, 1997). The child stood with toes behind a marked takeoff line, crouched and jumped forwards as far as possible. The child had to land two feet together. The horizontal distance jumped was measured from the takeoff line to the point of the child's body that landed closest to the starting point (Oja & Jürimäe, 1997).

5.3.4 Statistical analysis

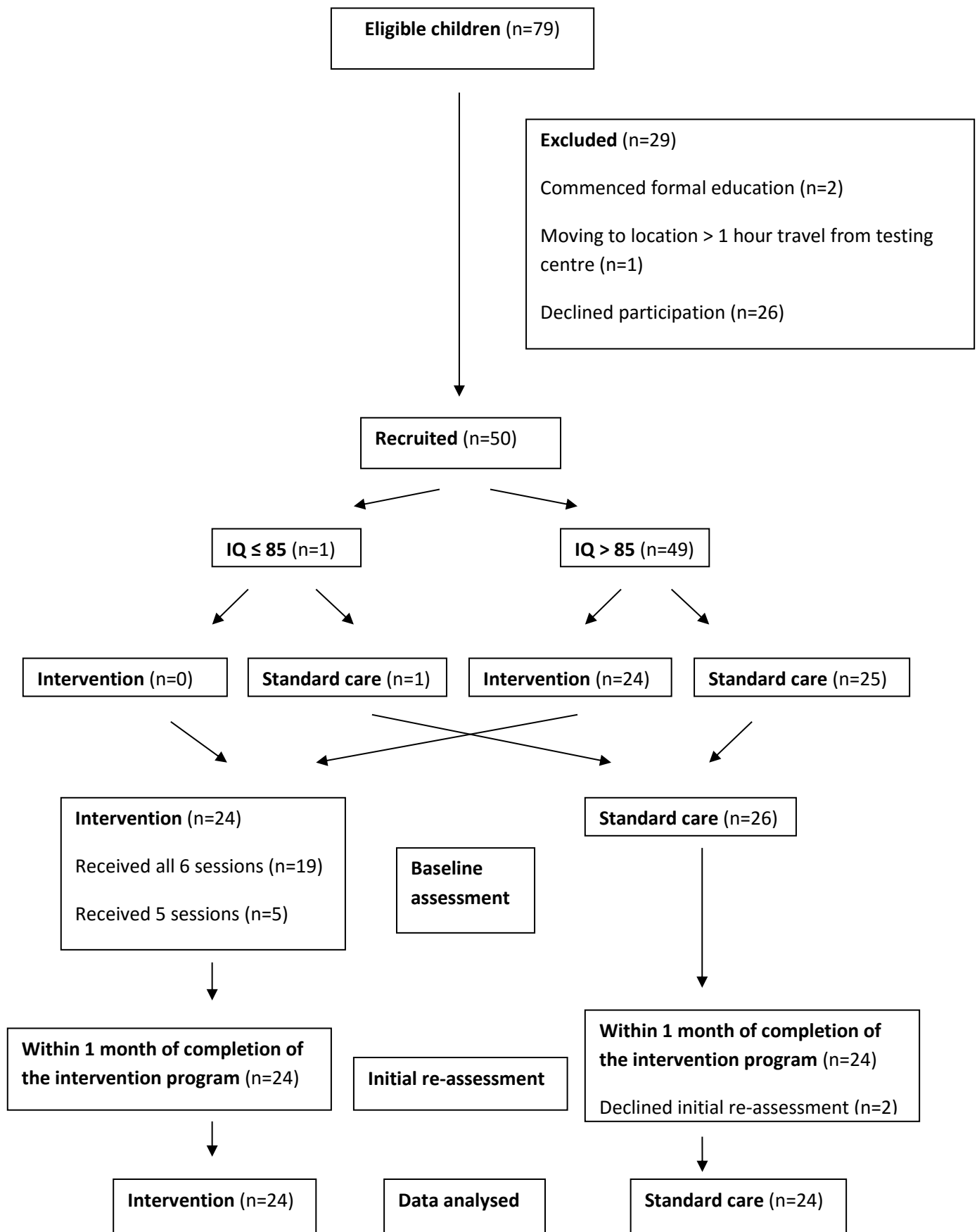
Prior to this RCT, a pilot study was conducted using the same selection criteria, measures and intervention. The pilot data demonstrated an average increase of 4 points from baseline to post-intervention on the primary outcome measure, the MABC-2 standard score. This represents approximately a 20% increase in the MABC-2 standard score from baseline. Therefore, assuming a modest increase in score in the standard care group of 0.5 points, and an average increase of 4 points with a common standard deviation of 4.4, 25 participants per group would be required.

Analysis was by intention-to-treat and was performed using SPSS version 22.0 (IBM Corporation, Armonk, NY, USA, 2013). Statistical significance was set at 5% (two-tailed). Differences between the two groups were examined, as well as relative change between groups and changes within each group over time. For continuous normally distributed data, means and standard deviations (SD) were determined and for categorical data, percentages. When comparing between groups, parametric or non-parametric analyses were used depending on the data distribution and type. Repeated measures analyses of variance were used for the primary outcome measure. Confidence intervals were calculated for secondary outcome measures. Mann-Whitney *U* tests evaluated non-parametric data. For categorical measures, the chi-square or Fisher's exact test was used to determine statistical significance.

5.4 Results

Seventy-nine children met inclusion criteria of which 50 participated (Figure 5.1). The recruitment period extended from July 2010 to February 2013 and all initial re-assessment of the children was completed by April 2013. Of the 29 who did not participate, two had commenced formal education and one child was about to move a considerable distance from the testing site. The remaining 26 children either declined or were unable to participate within the required timeframe. There were no significant differences between participants ($n=50$) and non-participants ($n=26$) in terms of perinatal and social factors or motor performance (Brown et al., 2015).

Figure 5.1 - Flowchart of recruitment of children



Of the 50 study children, 24 were randomised to intervention and 26 to standard care. However, two children in the standard care group declined initial follow-up. Therefore, 24 intervention children (mean corrected age 49.6 months, SD 2.4 months; 10 males) and 24 standard care children (mean corrected age 50.1 months, SD 2.6 months; 14 males) completed baseline and initial re-assessment. Perinatal and social characteristics of the groups are presented in Table 5.2. There were no significant differences between groups at baseline in terms of children classified as having DCD (MABC-2 percentile rank $\leq 15^{\text{th}}$ percentile) (Table 5.2).

Table 5.2 - Comparison between groups at baseline – perinatal/social factors and DCD classification

Factor	Intervention group (n=24)	Standard care group (n=26)	<i>p</i>
Perinatal/social			
Maternal age (years), mean (SD)	31 (6)	33 (7)	
Private health insurance, n (%)	18 (75)	12 (46)	
Antenatal steroids, n (%)	23 (96)	25 (100)	
Premature rupture of membranes, n (%)	4 (20)	13 (57)	
Caesarean section, n (%)	16 (67)	19 (76)	
Gestation (weeks), median (IQR)	26 (3.5)	26 (3)	
Birthweight (g), mean (SD)	799 (170)	875 (174)	
Male gender, n (%)	10 (42)	16 (62)	
Apgar at 5 mins < 7, n (%)	4 (17)	1 (4)	
Chronic neonatal lung disease, n (%)	11 (46)	4 (15)	
Late onset infection, n (%)	4 (17)	5 (19)	
Periventricular haemorrhage, n (%)	3 (13)	3 (12)	
Periventricular leukomalacia, n (%)	1 (4)	0 (0)	
Home oxygen program, n (%)	6 (25)	2 (8)	
DCD classification			
MABC-2 percentile rank $\leq 15^{\text{th}}$ %, mean (SD)	9 (38)	6 (23)	0.266

5.4.1 Changes between groups from baseline assessment to re-assessment

The changes in the two groups over time were compared, with no significant differences between groups on any of the measures (Table 5.3).

Table 5.3(a) - Comparison between groups over time – primary outcome

Variable	Baseline, mean (SD) <i>Intervention n=24; Standard care n=26</i>	Re-assessment, mean (SD) <i>Intervention n=24; Standard care n=24</i>	Change within group over time <i>P</i>	Change between groups over time <i>p</i>
<i>Manual dexterity</i>				0.104
<i>Intervention group</i>	8.4 (2.3)	9.0 (1.7)	0.183	
<i>Standard care group</i>	7.9 (2.6)	9.5 (2.3)	0.002	
<i>Aiming and catching</i>				0.637
<i>Intervention group</i>	9.1 (2.6)	10.5 (2.2)	0.010	
<i>Standard care group</i>	9.6 (2.9)	10.7 (3.4)	0.036	
<i>Balance</i>				0.475
<i>Intervention group</i>	7.7 (2.2)	8.7 (2.1)	0.001	
<i>Standard care group</i>	8.6 (2.1)	9.2 (2.9)	0.230	
<i>MABC-2 SS</i>				0.646
<i>Intervention group</i>	7.7 (2.3)	9.1 (1.8)	0.001	
<i>Standard care group</i>	8.3 (2.6)	9.9 (3.0)	0.001	
<i>MABC-2 PR(%)</i>				0.629
<i>Intervention group</i>	27 (22)	40 (20)	0.001	
<i>Standard care group</i>	34 (25)	50 (29)	0.002	

Table 5.3(b) - Comparison between groups over time – secondary outcomes

Variable	Baseline, mean (SD) <i>Intervention n=24; Standard care n=26</i>	Re-assessment, mean (SD) <i>Intervention n=24; Standard care n=24</i>	Mean (95% CI) difference between time-points for each group
<i>SLS-R (seconds)</i>			
<i>Intervention group</i>	4.0 (1.8)	7.3 (5.3)	3.3 (-5.19 to -1.44)
<i>Standard care group</i>	5.5 (2.9)	7.5 (5.7)	2.0 (-3.90 to -0.14)
<i>SLS-L (seconds)</i>			
<i>Intervention group</i>	3.5 (1.5)	5.5 (3.1)	2.0 (-2.99 to -1.05)
<i>Standard care group</i>	5.4 (4.3)	7.0 (4.2)	1.6 (-3.31 to 0.14)
<i>Lateral reach right (cm)</i>			
<i>Intervention group</i>	10.3 (3.6)	10.6 (2.9)	0.3 (-2.06 to 1.55)
<i>Standard care group</i>	9.9 (4.4)	10.6 (3.4)	0.7 (-2.76 to 1.43)
<i>Lateral reach left (cm)</i>			
<i>Intervention group</i>	10.0 (2.7)	11.0 (3.6)	1.0 (-2.40 to 0.53)
<i>Standard care group</i>	10.0 (4.3)	10.7 (3.0)	0.7 (-2.73 to 1.30)
<i>Standing long jump (cm)</i>			
<i>Intervention group</i>	67.5 (21.9)	73.6 (22.3)	6.1 (-11.39 to -0.83)
<i>Standard care group</i>	76.0 (20.3)	79.4 (21.0)	3.4 (-7.59 to 0.81)

5.4.2 Changes within each group from baseline assessment to re-assessment

In terms of the primary outcome, the intervention group improved significantly on all measures, except for MABC-2 manual dexterity standard score ($p=0.183$), whilst the standard care group made significant gains on all measures apart from MABC-2 balance standard score ($p=0.230$) (Table 5.3(a)). When considering within group change on secondary measures (Table 5.3(b)), exploration of the confidence intervals (CIs) showed that both groups improved their scores and that the intervention group improved more than the control group on all measures except lateral reach (right).

5.5 Discussion

The present study found that both groups improved over time and that there was no difference in change in motor performance between the groups in the short term. In such a short period of time, children benefited from both compliance with standard care and intervention, which emphasises the efficacy of current best practice and that intervention is multi-faceted. The positive outcome to standard care was somewhat unexpected and was perhaps related to parents of these children being diligent and motivated to follow advice provided by the activity booklets. Further explanations for both groups improving may be related to the general process of maturation and improved proficiency of skills with time, as well as the relatively short intervention period. However, it is important to consider whether the gains attained by both groups will be sustained or if differences between the groups will emerge over time. Motivation and compliance within the standard care group may decline to a greater extent than within the intervention group when longer term effects are considered. This may be due to the parents of the children in the intervention group having a greater understanding of their child's difficulties and how to best address these difficulties to optimise their child's development.

It may be that the positive changes in the standard care group masked the gains attained by the intervention group, which is why it is important to reflect on the changes within each group over time. In this case, there were different patterns of improvement in each group, with the intervention group appearing to make greater gains than the standard care group, but these did not necessarily reach significance. In terms of the primary outcome, the intervention group improved significantly on all measures except manual dexterity, whilst

the standard care group improved significantly on all measures apart from balance skills. A possible explanation for these findings may be associated with differing parental focus amongst each group.

Another reason for the intervention group having greater gains in balance may be linked to postural control, which underpins performance in this area (Shumway-Cook & Woollacott, 2007). Postural control was a key component of the intervention program and activities were specifically designed to target further development of postural control amongst children in this group each week. Therefore, even though both groups improved on postural control measures, perhaps the emphasis on postural control development within the intervention program accounts for the intervention children making stronger gains on these measures than the standard care group.

Group-based intervention studies have been conducted amongst children with DCD or CP (Auld & Johnston, 2014; Pless, Carlsson, Sundelin, & Persson, 2000; Watter & Bullock, 1989), but the current study is unique in that it specifically targeted non-disabled ELBW children of a younger age than in previous studies. As non-disabled ELBW children are at risk of school readiness issues and performance at four years is predictive of later performance, the current study provides evidence that some deficits that these children experience may be improved. Perhaps then in the future, strategies presented in this study should be part of routine follow-up of these children until school commencement.

Limitations to the current study included time constraints. The six week intervention period was chosen due to time issues and for practicality of operation. However, the use of this relatively short intervention timeframe, in conjunction with both groups receiving the activity booklets, may have contributed to the lack of group differences. Group-based intervention studies in which the intervention has continued over a longer period have reported more favourable outcomes (Pless, Carlsson, Sundelin, & Persson, 2000; Watter & Bullock, 1989). However, despite the short intervention period, both groups still made gains, which is a positive finding. Measuring compliance with the activity booklets and the home exercise programs may have further informed the results. Parents of the intervention group were advised to encourage their child to perform 20-30 minutes of their home program per day and were provided with a table to tick-off upon completion of exercises on a daily basis. However, some families found this commitment difficult and

there was the potential for unreliable feedback from parents. Therefore, compliance with activity booklets or home program was not formally recorded.

Another limitation is that due to ethical considerations, it was considered appropriate that the standard care group should receive the activity booklet. This may well have influenced the natural development of these children. Also, it could be argued that there was a lack of control variables.

Additionally, due to the characteristics of the study children, the outcome measures may not have been sensitive enough to detect some changes that may have occurred. The MABC-2 is not specifically designed or advocated to be a pre/post intervention tool. However, as it has been used as such in previous studies (including the pilot study that lead to the RCT), the MABC-2 was considered to be the best choice of assessment tool. As this RCT is part of a larger study, perhaps when other measures are reviewed, such as the Goal Attainment Scaling (GAS) (Kiresuk, Smith, & Cardillo, 1994) this will be useful in demonstrating whether targeted activity improved in the intervention group.

Also, tight inclusion criteria meant a relatively small sample size in the present study, which needs to be taken into account when extrapolating findings of this RCT. The strict inclusion criteria ensured that the group-based model was effective. This group approach would not be suitable for children with more severe impairments, where individual-based therapy involving a multi-disciplinary team would be more appropriate.

5.6 Conclusion

Group-based intervention and adherence to best practice both yield positive outcomes in the short term amongst ELBW or extremely preterm four year old children with minimal to mild neurodevelopmental impairments. For optimal results and enhancement of participation levels in society, intervention may be more favourable, especially given the persistent nature of problems amongst these children. Group-based intervention is an economically viable model of service delivery that is aligned with current intervention recommendations. Before advocating for implementation of this approach, it would be useful to further consider advice that is delivered and adhered to in the best possible way

for this cohort of children. Additionally, further studies investigating the longer term effects of group-based intervention compared to standard care amongst these children, as well as the impact of these approaches on other areas of development, such as behaviour and functional performance, will be undertaken.

5.7 Additional information

As a result of study II, null hypothesis II should be accepted as between group comparisons demonstrated that the short term effects of intervention on motor co-ordination, postural stability and limb strength were no different to standard care in the non-disabled ELBW children.

CHAPTER 6

STUDY III A randomised controlled trial of group-based physiotherapy intervention for non-disabled ELBW children: one year follow-up of motor and postural outcomes

Findings from study II highlighted the importance of considering the longer term impact of intervention compared to standard care on motor and postural outcomes of the non-disabled ELBW children. Therefore, this provided the foundations for study III.

Publication: to be submitted to Early Human Development following publication of study II
Brown, L., Burns, Y. R., Watter, P., Gibbons, K. S., Gray, P. H. A randomised controlled trial of group-based physiotherapy intervention for non-disabled ELBW children: one year follow-up of motor and postural outcomes.

6.1 Abstract

Aim: The short term impact of group-based physiotherapy intervention compared to standard care on motor co-ordination, postural stability and limb strength of non-disabled ELBW children at four years of age has previously been reported. This study explored the effect of the intervention one year post baseline.

Method: Fifty four-year old children (born <28 weeks gestation or with birth weight <1,000g) with minimal/mild motor impairment, were randomised to intervention (n=24) or standard care (n=26). Intervention included six weekly group-based sessions and a goal-based home program. Standard care group received best practice advice. Motor co-ordination, postural stability and limb strength of all children were re-assessed at one year post baseline.

Results: 48 (96%) of the children completed the study. For the total cohort, MABC-2 manual dexterity, aiming and catching and total score declined from baseline to one year follow-up, with all, except aiming and catching reaching significance ($p < 0.001$ to 0.050). MABC-2 balance scores and postural stability and limb strength were significantly better,

except for left lateral reach ($p < 0.001-0.034$). No significant differences between groups were demonstrated.

Interpretation: For the whole cohort, despite short term gains, at the one year follow-up, functional skills improved but motor performance declined; no between group differences were apparent.

6.2 Introduction

Intervention amongst non-disabled extremely low birth weight (ELBW; birthweight < 1,000g) children is desirable as it has been established that long term neurodevelopmental impairments remain high in this group (Danks et al., 2013; Hutchinson et al., 2013). In particular, problems with motor co-ordination and postural stability have been identified amongst non-disabled ELBW children and these problems may become more evident and persistent with age (Burns et al., 2009; Goyen & Lui, 2002, 2009). There are widespread implications of such impairments for these children, including adverse effects on academic functioning and social success, an increased demand on educational resources, parenting stress and potential financial and psychological issues (Bhutta et al., 2002; Reijneveld et al., 2006).

In order to further explore the role and outcomes of intervention amongst non-disabled ELBW children, we commenced this process by firstly reporting on how these children perform at four years of age (Brown et al., 2015). The decision to target this age group was based on concerns about non-disabled ELBW children lacking school readiness and the limited services available for them in the community (Roberts et al., 2011). It has been highlighted in the literature that there is a need to further consider this concept of school readiness, as well as a need for more interventions at school-age to reduce rates of poor long term outcomes amongst high-risk children (Doyle et al., 2014). Therefore, next we examined the impact of a group-based physiotherapy intervention program compared to standard care on motor co-ordination, postural stability and lower limb strength amongst these children (study II). In summary, we found that both group-based intervention and compliance with best practice advice resulted in positive short-term outcomes, with both groups improving across time.

However, as previously mentioned, it is recognised that neurodevelopmental problems amongst ELBW children are ongoing in nature and, subsequently, there is a need for intervention that has a lasting effect. Studies investigating the long term impact of intervention amongst preterm children are limited and of those that do exist, they are difficult to compare due to heterogeneity between studies (Spittle, Orton, et al., 2012). Therefore, the purpose of this study was to re-assess our cohort of non-disabled ELBW children at one year post baseline assessment to determine the longer term effect of brief group-based intervention compared to standard care on motor co-ordination, postural stability and limb strength. This approach would enable performances to be compared to normative data, but would also allow comparison between groups and within each group across time.

Our specific primary aims included considering the change in the motor performance of the whole cohort across time. We expected that the trend would be an overall improvement due to the process of maturation. Additionally, we aimed to compare the groups across time as we anticipated that intervention would provide superior outcomes to best practice advice, which is an important issue as there is a need for cost effective management for these children. We hypothesised that if problems persisted or were more pronounced amongst the children compared to the previous study looking at short term changes, then this would demonstrate that our cohort of children are comparable to what is reported in the literature, regardless of the intervention or advice provided. Our secondary aims were to explore the functional changes in postural control, balance and strength of the whole cohort across time, as well as between groups.

6.3 Methods

6.3.1 Study design

This study is a continuation of the initial phase of our RCT which examined the short term impact of group-based physiotherapy intervention compared to standard care (study II). The RCT was approved by the Mater Health Services Human Research Ethics Committee and the Medical Research Ethics Committee of the University of Queensland and was registered with the Australian New Zealand Clinical Trials Registry

(ACTRN12613000950763). Details regarding the study design, participants, recruitment, randomisation, intervention and measurements have previously been described (Brown et al., 2015)(study II). A summary of the study is presented below.

6.3.2 Participants

Children were born between May 2005 and November 2008, had a birth weight of < 1,000g or a gestational age of < 28 weeks (extreme prematurity) and were managed in the Neonatal Intensive Care Unit at the Mater Mothers' Hospital, Brisbane, Australia. For conciseness, the children in this study will hereafter be referred to as ELBW. Eligible children lived within one hour travel of the testing centre.

Children were excluded if they had significant congenital anomalies, neurological impairments, visual/hearing impairments not corrected by assistive devices or if their parents/guardians did not speak English.

6.3.3 Recruitment

Children were recruited based on their assessment results at their four year (age corrected for prematurity) Growth and Development clinic review at the Mater Mothers' Hospital. Eligible children had a score from the Neurosensory Motor Developmental Assessment (NSMDA) (Burns et al., 1989) of 9 to ≤ 12 (minimal to mild deviation from normal) and an IQ of > 70 (<70 corresponds to delayed development) on the Stanford-Binet Intelligence Scales (Roid, 2003). Children were four to four and a half years (corrected age) when commencing involvement in the study and had not started formal education.

6.3.4 Procedures

Baseline assessment (assessment 1)

Following consent, children underwent baseline assessment (assessment 1) by trained paediatric physiotherapists who had minimal information about the children. A set testing protocol was adhered to, which included the Movement Assessment Battery for children second-edition (MABC-2), Single Leg Stance (SLS) test, Lateral Reach test and Standing

Long Jump test. Data in relation to perinatal and social history was collected from medical records.

Randomisation

After assessment 1, children were randomly assigned to intervention or standard care group, stratified according to their cognitive abilities from the Stanford Binet (Roid, 2003) with $IQ \leq 85$ / > 85 . Randomisation was performed by the Mater Mothers' Research Centre (MMRC) statistician and this was in the form of variable block randomisation. Twins were randomised to the same group, due to the nature of the intervention. Assignment to group was concealed by using sealed opaque envelopes prepared by a member of MMRC external to the study team. These envelopes were identified by stratification group and consecutively numbered. A member of the research team then allocated these envelopes to children based on the order in which they were booked in for assessment 1. Following assessment 1, parents/guardians were notified which group their child had been assigned to by the physiotherapist leading the intervention. Assessors were blinded to group allocation.

Intervention

Intervention was group-based with three to four children per group and combined traditional physiotherapy and task-oriented approaches. These approaches and their application to children with developmental co-ordination disorder (DCD) have been described in the previous study (study II).

Intervention consisted of a six week structured physiotherapy program led by a trained paediatric physiotherapist. This physiotherapist had no involvement in the assessment of the children. The weekly sessions were approximately one hour plus 20-30 minutes for home program explanation and parent discussion. The complexity of the home program and the intervention itself were progressed over time.

The standard care group received 'optimal care' which involved best practice advice and an informal booklet of general age-appropriate activities. Children in the intervention group also received this booklet. Families of children in both groups were emailed on a two monthly basis throughout the study period, to maintain contact with the families and to provide a forum for families to ask any questions. It was anticipated that regular contact

with the families would also assist with our retention rate. Children in both groups were entitled to access other therapies at any time throughout the entirety of the study.

Short term follow-up (assessment 2)

All children were re-assessed on the tests they underwent at baseline within one month of the children in the intervention group completing the program.

One year follow-up (assessment 3)

All children underwent re-assessment again at approximately 12 months post assessment 1. This involved the same tests that were conducted at assessment 1 and 2.

6.3.5 Measurements

Details regarding the outcome measures have previously been reported (study II), therefore, they will be explained in brief in this study.

Primary Outcome

Movement Assessment Battery for Children second-edition (MABC-2)

The MABC-2 was used to assess motor co-ordination (Henderson et al., 2007). The test includes measures of manual dexterity, aiming and catching, and balance. When scoring the MABC-2, component scores are converted into standard scores and percentiles, which enable the child to be compared to typically developing children of the same age. According to the manual, a percentile rank $\leq 15^{\text{th}}$ percentile represents at risk of or significant movement difficulty. The MABC-2 percentiles are determined according to the specific age band that the child falls within. The manual states that the results provide a standard score and a percentile that are comparable to norms, so it should not matter if a child is assessed in one age band and then re-assessed in another. To allow more accurate comparison of each child's individual changes between assessment 1 and 2, the same age band at assessment 1 was also used for assessment 2. At assessment 3, the child's result was calculated according to their age band corrected for prematurity.

Secondary Outcomes

For all of these tests, a set testing protocol and standard instructions were used. Timed single leg stance (SLS) and lateral reach were used to assess functional postural control

and balance. Reliable and valid measurements of postural stability in children are limited (Westcott et al., 1997) and norms for these tests are lacking, but the above tests are functional and are often used in the clinical context. The standing long jump was used to assess functional lower limb strength and control. There is evidence supporting its reliability in children (Oja & Jürimäe, 1997).

6.3.6 Sample size

Sample size was calculated as described previously (study II) based on pilot data. The pilot data demonstrated that 25 participants per group would be required.

6.3.7 Statistical analysis

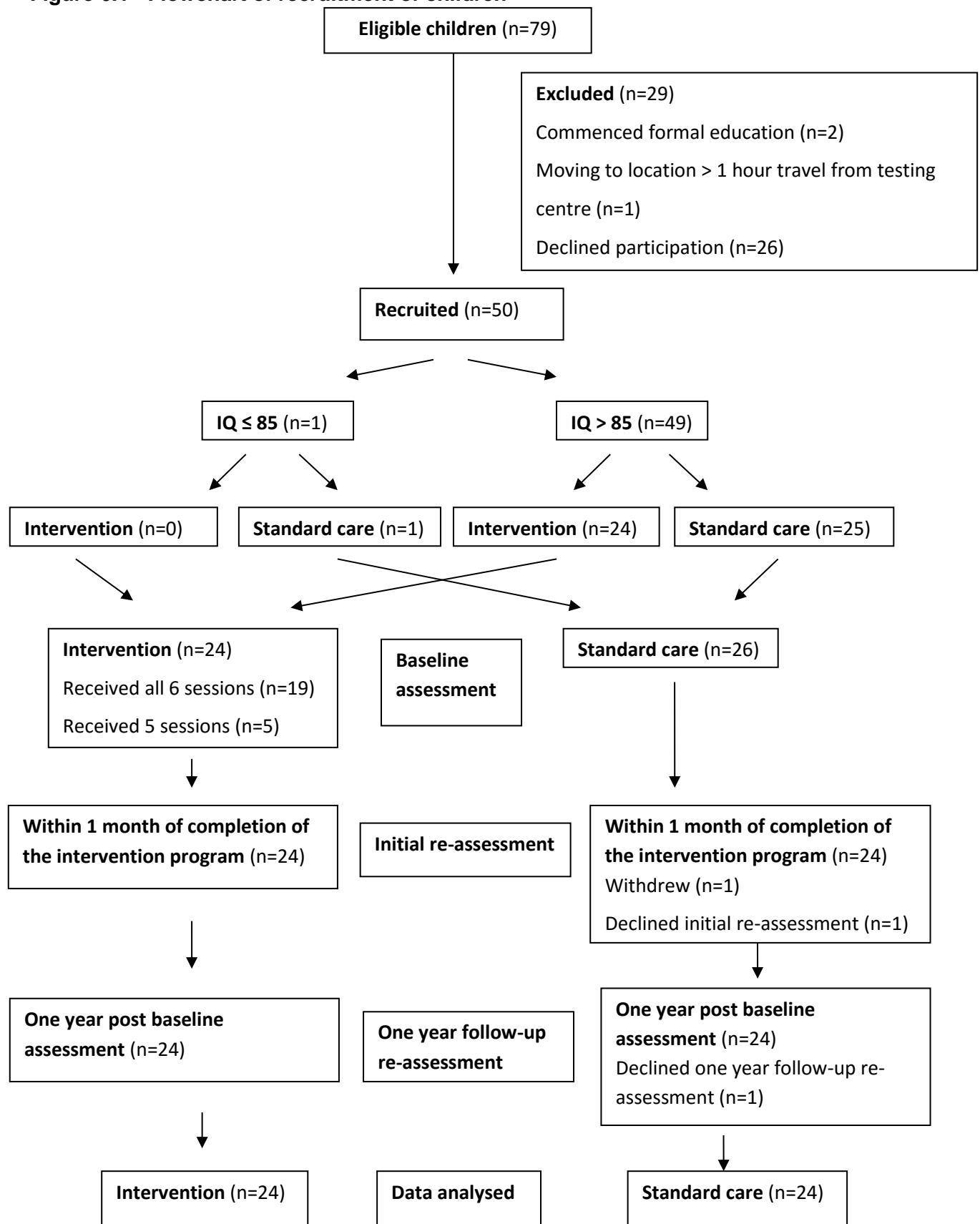
All analyses were performed using SPSS version 22.0 (IBM Corporation, Armonk, NY, USA, 2013). Prior to the analyses, the distribution of the data was explored to ensure that it was acceptable for the tests used. The groups were combined and considered as a whole, to determine the pattern of change of the children overall, as well as between time points (from assessment 2 to 3 and from assessment 1 to 3). Additionally, comparison was made between groups from assessment 2 to 3 and from assessment 1 to 3. Furthermore, within group change was analysed across and between time points. Analysis of variance was conducted to determine the change in scores over the three time points and between time 1 and time 3; and to identify any group by time interaction. Statistical significance was set at 5% (two-tailed).

6.4 Results

Between July 2010 and February 2013, 79 children met the inclusion criteria (Figure 6.1). Of these, 50 children were recruited to the study, including four sets of twins. There were no significant differences in perinatal and social factors between recruited children and non-participants (Brown et al., 2015). The 50 recruited children were randomised to either intervention (n=24) or standard care (n=26) groups. At assessment 2, 48 (96%) children returned with one child in the standard care group withdrawing from the study at this point and one child in the standard care group declining this review. At assessment 3, of the 49 remaining children, 48 (96%) children were evaluated, with one further child in the

standard care group declining this review. All of assessment 3 was completed by February 2014.

Figure 6.1 - Flowchart of recruitment of children



During the intervention period, two (8%) children (one male and one female) in the intervention group attended occupational therapy. Some children received allied health therapy between re-assessment and the one year follow-up re-assessment: seven (29%) children in the intervention group (three males and four females) and four (17%) children in the standard care group (all males). Allied health therapy included occupational therapy, physiotherapy, speech therapy, vision therapy, as well as a combination of these therapies.

6.4.1 Change in whole group across all time points and between time points

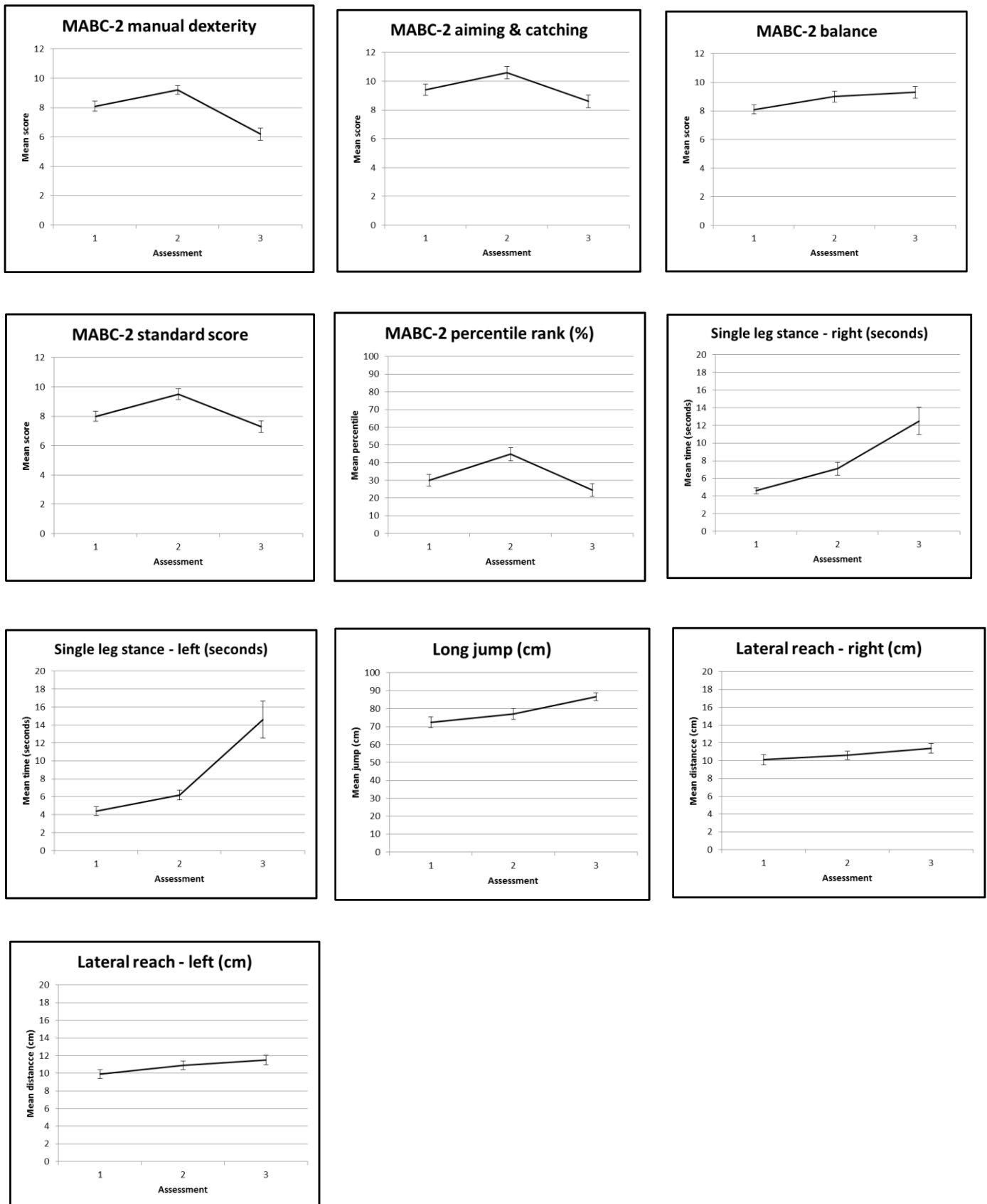
When considering the whole group across all time points, that is, from assessment 1 to 2 to 3, Anova revealed that all measures changed significantly, except lateral reach (means shown in Table 6.1). For all measures except lateral reach, $F_{(2,45)}$ ranged from 4.73 to 36.95, p ranged from < 0.001 to 0.005. Mean scores and standard errors at each time point for the whole group are presented in Figure 6.2, demonstrating the pattern of score change over time. Apart from MABC-2 balance standard score, which improved from time 1 to time 3, all MABC-2 measures declined over this period. In other words, the direction of change altered between assessment 1 to 2 and assessment 2 to 3, indicating that the gains made at assessment 2 were not sustained and the children performed more poorly at assessment 3. Functional tasks exhibited a different pattern, with SLS, lateral reach and long jump improving steadily across times. Significance of changes from time 1 to time 3 are also shown in Table 6.1. Apart from MABC-2 balance standard score, which improved from time 1 to time 3, all MABC-2 measures declined over this period. All reached significance except for aiming and catching scores.

Table 6.1 – Whole group means and standard deviations for all times & change from time 1 to 3 (n=48)

<i>Outcome measure</i>	<i>Mean (SD)</i>	<i>Change T1-T3</i>
MABC-2 manual dexterity SS	T1 = 8.1 (2.4) T2 = 9.2 (2.1) T3 = 6.2 (2.9)	p < 0.001
MABC-2 aiming & catching SS	T1 = 9.4 (2.8) T2 = 10.6 (2.9) T3 = 8.6 (3.0)	p = 0.074
MABC-2 balance SS	T1 = 8.1 (2.2) T2 = 9.0 (2.6) T3 = 9.3 (2.9)	p = 0.008
MABC-2 SS	T1 = 8.0 (2.4) T2 = 9.5 (2.5) T3 = 7.3 (2.7)	p = 0.050
MABC-2 PR (%)	T1 = 30.0 (23.3) T2 = 44.8 (25.6) T3 = 24.5 (25.0)	p = 0.115
Single leg stance (R) (sec)	T1 = 4.6 (2.4) T2 = 7.1 (5.1) T3 = 12.5 (10.6)	p < 0.001
Single leg stance (L) (sec)	T1 = 4.4 (3.4) T2 = 6.2 (3.8) T3 = 14.6 (14.4)	p < 0.001
Lateral reach (R) (cm)	T1 = 10.1 (4.0) T2 = 10.6 (3.2) T3 = 11.4 (3.9)	p = 0.034
Lateral reach (L) (cm)	T1 = 9.9 (3.6) T2 = 10.9 (3.3) T3 = 11.5 (3.7)	p = 0.174
Long jump (cm)	T1 = 72.3 (21.1) T2 = 77.0 (21.6) T3 = 86.6 (15.6)	p < 0.001

Abbreviations: T1, baseline assessment; T2, short term re-assessment; T3, one year follow-up re-assessment; MABC-2, Movement Assessment Battery for Children second-edition; SS, standard score; PR, percentile rank; (R), right; (L), left.

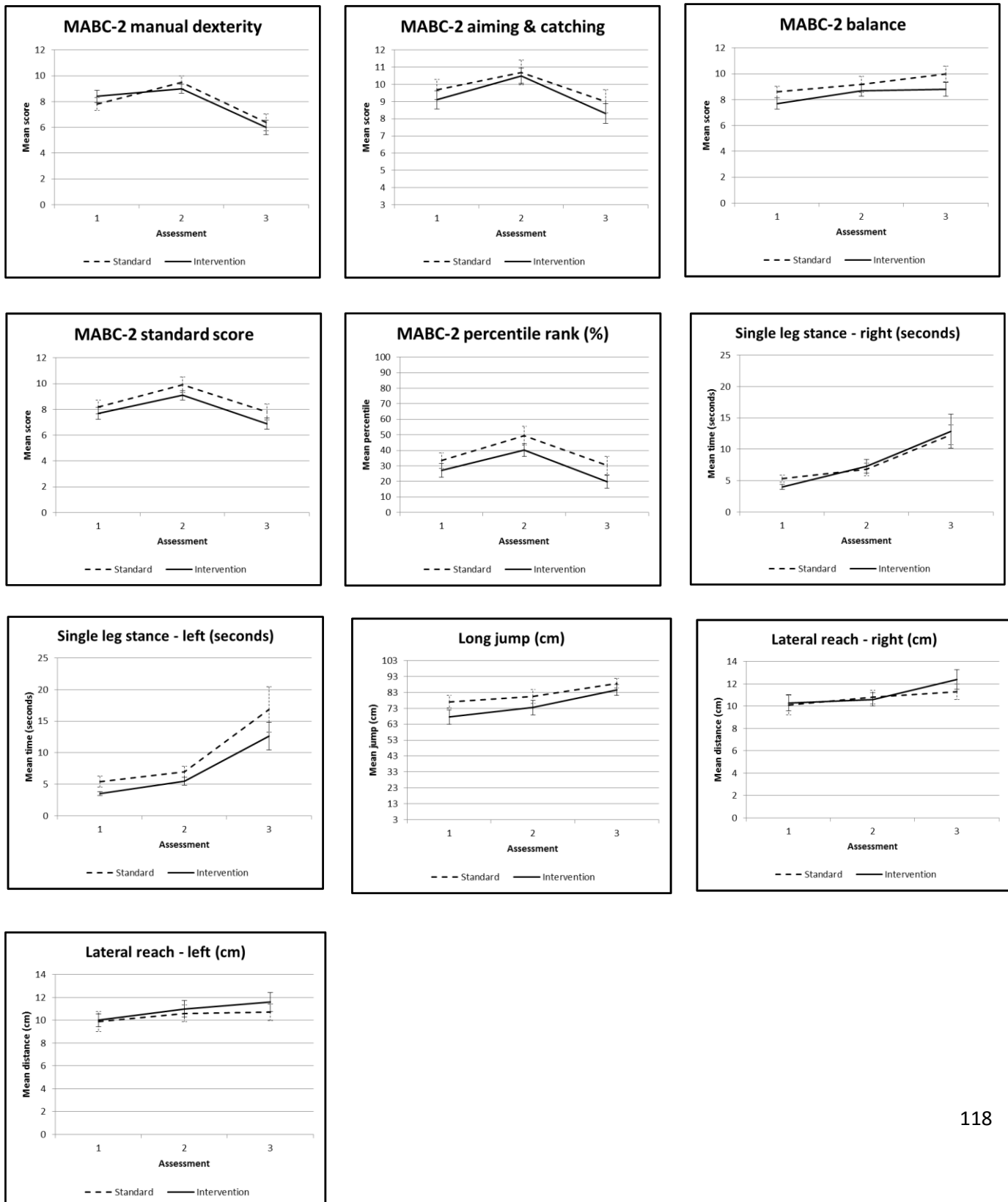
Figure 6.2 - Mean scores and standard errors at each time point for whole group – primary and secondary outcomes



6.4.2 Changes between groups across all time points

Anova revealed no group by time interaction on any measures. Mean scores and standard errors at each time point for intervention and standard care groups are presented in Figure 6.3.

Figure 6.3 - Mean scores and standard errors at each time point for intervention & standard care groups – primary and secondary outcomes



6.4.3 Within group changes across all time points and between each time point

Means and standard errors for scores at each time for each group are shown in Figure 6.3. On the MABC-2, except for balance standard scores, both groups showed improvements from time 1 to 2, and a decline from time 2 to 3, as well as a decline from time 1 to time 3. The MABC-2 balance standard scores of both groups improved steadily across times. The pattern of change seen in functional tasks of SLS, lateral reach and long jump was similar to the whole cohort, with steady improvements in each group between all times.

6.5 Discussion

The current study found that at one year follow-up, the impact of group-based intervention undertaken by non-disabled ELBW children at four years of age is comparable to that of best practice advice. A similar finding of nil significant differences between groups was evident in the previous study investigating the short term effects of intervention compared to standard care (study II). Both groups received best practice advice, which included an activity booklet and regular contact with the families. This may have motivated families of both groups to comply with the advice provided and therefore optimised performance of all the children. Also, the intervention program aimed to address both activity and participation goals rather than just improving specific motor delays, which may have contributed to the lack of differences between groups.

We were hopeful that this cohort of non-disabled ELBW children would continue to improve on motor and postural outcomes over time. The whole group did make significant gains on postural stability and lower limb strength measures, which is important as it indicates that the children improved their own performances (independent of age) as a result of intervention or best practice advice and maturation. This functional improvement represents individual change amongst the children. The general pattern on the primary outcome measure, the MABC-2, which compares children's performance to age equivalent norms, was that the overall standard score of the children changed across times, declining significantly between time 1 and time 3, although it was still within the normal range. Perhaps this is not surprising given the persisting nature of motor problems amongst the

non-disabled ELBW population reported in the literature (Burns et al., 2009; Goyen & Lui, 2002, 2009). Additionally, the children progressed by one to three age bands on the MABC-2 at assessment 3 according to its usual use. This meant that scores for the study children were based on norms of children who were in one to three age bands higher than those used at assessment 1. As children advance through each age band, it is anticipated that performance will also improve and therefore test norms increase in each age band. This need to meet the more demanding (older or higher) scoring standards could have contributed to the increase in disparity between the study children and age norm expectations over time.

This same pattern of change in motor performance was seen within each group, as measured by the MABC-2, declining over the one year study period and this mainly occurred from the short to longer term re-assessment. Both intervention and best practice advice had short term benefits, but the gains made on the primary motor measure were mostly not sustained, irrespective of any effects of maturation. However, the overall percentile rank of the children on the MABC-2 in both groups remained above the 15th percentile. There were improvements in SLS and standing long jump across time in both groups, suggesting that individual growth occurred due to the longer term impact of intervention and best practice advice as well as possible maturation. This finding of a more lasting effect on functional measures, especially for the intervention group where changes were greater, provides a catalyst for considering the long term impact of intervention compared to standard care on other areas of development, such as behaviour. It would also be useful to employ studies using repeated short interventions or a longer intervention period to see if gains were more likely to be maintained. However, the results of this study indicate that despite individuals making personal progress, the gap between these children and age equivalent MABC-2 norms continued to widen over the 12 month study period, suggesting declining performances in the longer term.

Although there are limited studies addressing the long term impact of early intervention programs amongst the preterm population, of those that do exist, there is some evidence indicating improvements in motor and cognitive outcomes in the short term (Spittle, Orton, et al., 2012). These programs have had little long term influence on motor outcomes. However, a more lasting positive effect on cognition and behaviour has been reported (Nordhov et al., 2012; Spittle, Orton, et al., 2012). It could be suggested then that as our

intervention program did not lead to improvements on motor outcomes at the one year follow-up, our findings are comparable to findings of other studies. We acknowledge though that there is a great deal of heterogeneity between our study and others in the literature, therefore comparisons are limited.

Strengths of our study included our high retention rate. In addition, as far as we are aware, our group-based physiotherapy intervention program amongst non-disabled ELBW children at four years of age is the first of its kind. The current study showed that all children improved their performance on functional tasks over the 12 month period, especially those children in the intervention group. Furthermore, both intervention and best practice advice incorporated an education component, although a greater emphasis was placed on education within the intervention group. Perhaps this made parents/guardians more aware of their child's impairments and the implications of these on the activity and participation levels of their child. This may have contributed to the higher number of children accessing therapy between assessment 2 and 3, particularly in the intervention group. These children who accessed therapy may have performed more favourably at assessment 3 than if they had not been exposed to therapy. The importance of involving parents/guardians in the care of their child and the possible benefits this may have on neurodevelopmental outcomes of preterm children has been demonstrated (Vanderveen et al., 2009).

Limitations of this study include the relatively short intervention period and the appropriateness of using the MABC-2 as our primary outcome measure. However, time constraint issues limited the intervention period and the lack of a more suitable tool influenced our decision to use the MABC-2. Furthermore, we did not measure compliance with the activity booklets and the home exercise programs, although even if this had been formally recorded, reliability may have been questionable. Finally, the standard care group did receive the activity booklet due to ethical considerations and this may have had an impact on the natural course of development of these children.

6.6 Conclusion

The longer term impact of brief group-based intervention was no different from standard care on motor or postural control measures at five years of age amongst non-disabled ELBW children. Both intervention and best practice advice had short term benefits, as well as longer term improvements on functional measures, representing individual growth over time. However, exposure to either intervention or standard care was not sufficient to ameliorate against the ongoing nature of motor problems amongst these children. This study highlights the complexity of intervention. Perhaps input over a longer timeframe or repeated short periods of input would be useful in the future. In the current financial climate, advocating for compliance with best practice advice may be the more cost effective approach. However, further investigation into the impact of intervention compared to standard care on other areas of development, such as behaviour and participation, is necessary before more definitive conclusions can be reached.

6.7 Additional information

Null hypothesis III associated with study III should be accepted as there was no difference in motor and postural outcomes between non-disabled ELBW children who underwent intervention and those who received standard care at one year follow-up.

CHAPTER 7

STUDY IV GAS to explore effect of group-based physiotherapy intervention on personal growth of non-disabled ELBW children

Findings from the study series thus far have not demonstrated any major differences between intervention and standard care on development of the non-disabled ELBW children. Therefore, study IV was included to focus on the intervention group only. In particular, as goal performance was measured in this group, it was decided to explore the effect of intervention on personal change amongst these children.

Publication: submitted to Pediatric Physical Therapy

Brown, L., Burns, Y. R., Watter, P., Gray, P. H. GAS to explore effect of group-based physiotherapy intervention on personal growth of non-disabled ELBW children.

7.1 Abstract

Purpose: To investigate the effect of group-based physiotherapy intervention on functional change amongst non-disabled extremely low birth weight (ELBW) children at four years using the Goal Attainment Scaling (GAS). To explore correlations between GAS scores and motor/postural outcomes and gender.

Methods: Twenty-four four-year old children (born <28 weeks gestation/birth weight <1,000g) with minimal/mild motor impairment completed six group-based weekly intervention sessions and a goal-based home program. Pre/post intervention assessments evaluated GAS, Movement Assessment Battery for Children Second-Edition (MABC-2), postural stability and limb strength.

Results: GAS T-score of the group improved, exceeding the expected goal of “0” score after intervention (mean=58.17, SD=0.82). GAS mean T-score and MABC-2 percentile were moderately correlated ($p=0.043$). Females improved more than males ($p=0.047$).

Conclusions: Intervention was effective with goal attainment at the expected level or beyond. Goal attainment was related to motor co-ordination. Individuals with better motor skills post intervention, were more successful in reaching goals.

7.2 Introduction

It has been established for some time that non-disabled extremely low birth weight (ELBW; birthweight < 1,000g) children commonly present with mild neurodevelopmental impairments that are persistent in nature (Burns et al., 2009; Goyen & Lui, 2002, 2009). However, as these children have no major impairments and are otherwise healthy and able-bodied, they are often overlooked, with minimal support services available for them (Burns et al., 2004). Therefore, intervention amongst these children, in particular, the role of intervention and how to measure its effectiveness, requires further exploration. We wanted to explore this issue amongst four-year old ELBW children as this is a critical time-point for them, being on the cusp of commencing formal education. Additionally, teachers and parents often report that these children lack school readiness (Roberts et al., 2011).

We have previously conducted a randomised controlled trial (RCT) investigating the short-term motor and postural benefits of group-based physiotherapy intervention compared to compliance with best practice advice in a cohort of non-disabled four-year old extremely preterm (born <28 weeks gestation) or ELBW children. Detailed exploration of personal gains made by the intervention group were also important for parents to recognise that these children progressed, even though performance on standardized tests may have been poor. This was possible by using Goal Attainment Scaling (GAS) (Kiresuk & Sherman, 1968). GAS provided a means of evaluating functional change of the individual and assisted in determining the effectiveness of the program. Inclusion of GAS was important as it had particular relevance to the child and their family.

Due to its versatility, GAS can be applied to all levels within the International Classification of Functioning Disability and Health (ICF) framework, whether the domain be impairment, activity or participation (World Health Organization, 2001). There is evidence supporting the use of GAS in the paediatric rehabilitation setting (Steenbeek et al., 2007). In particular, it has been shown to be responsive and sensitive to change and it has acceptable content validity. Additionally, it has been demonstrated that GAS was sensitive to identifying change amongst children with sensory integration dysfunction following occupational therapy intervention (Miller et al., 2007). It has been suggested that GAS may be more suitable for detecting incremental change rather than milestone attainment

amongst children (Morgan et al., 2015). However, in terms of the reliability of GAS when applied to paediatrics, evidence is somewhat lacking.

This study set out to explore whether our group of non-disabled extremely preterm or ELBW four-year old children made short term functional gains measured by GAS as a result of intervention. Furthermore, we aimed to investigate whether these functional changes were related to motor co-ordination, postural stability and limb strength performance immediately after intervention. Finally, we examined the association between goal attainment and gender as male gender has been identified as a risk factor for poorer performance amongst non-disabled ELBW children (Zanudin, Burns, et al., 2013).

7.3 Methods

7.3.1 Study design

This study forms part of a RCT that compared the effects of group-based physiotherapy intervention to standard care on motor co-ordination, postural stability, limb strength, and behaviour of four-year old extremely preterm or ELBW children. The RCT was approved by The Mater Health Services Human Research Ethics Committee and The Medical Research Ethics Committee of the University of Queensland and was registered with the Australian New Zealand Clinical Trials Registry (ACTRN12613000950763). Details regarding some elements of the RCT have been previously described (Brown et al., 2015). In our current study, we focused on short term goal attainment amongst the intervention children only.

7.3.2 Participants

Twenty-four children were randomised to the intervention arm and were included in this study exploring the impact of intervention on GAS scores and relationships between GAS scores and other outcome measures. Children were recruited between July 2010 and February 2013 as part of the physiotherapy intervention RCT and had completed assessment by April 2013. Mean corrected age of the children at baseline was 49.6

months (SD 2.4 months). There were 14 females and 10 males. Mean birthweight of the children was 799g (SD 170g) and median gestational age was 26 weeks (range 24 – 31 weeks). Mean birthweight was 797g (SD 182g) for females and 801g (SD 162g) for males.

We have previously described the characteristics of these children (Brown et al., 2015). The children were born between May 2005 and November 2008 and were managed in the Neonatal Intensive Care Unit at the Mater Mothers' Hospital, Brisbane, Australia. They had a birth weight of < 1,000g or a gestational age of < 28 weeks (hereafter referred to as ELBW). Children lived within one hour travel of the testing centre. Children were four to four and a half years corrected for prematurity when enrolling in the study and had not started formal education. In the case of extreme prematurity, it is usual to continue using corrected age until the child is five years of age or until formal school education has commenced (DiPietro & Allen, 1991). Additionally, children had attended the Mater Mothers' Hospital Growth and Development clinic follow-up assessment at four years (corrected age) and had a score from the Neurosensory Motor Developmental Assessment (NSMDA) (Burns, 2014) of 9 to ≤ 12 (minimal to mild deviation from normal) and an IQ of > 70 on the Stanford-Binet Intelligence Scales (Roid, 2003).

Exclusion criteria were: major congenital anomalies, diagnosed neurological impairments, a visual impairment not corrected by corrective lenses, a hearing impairment not corrected by aids, parents/guardians who did not speak English and families that could not commit to the study attendance requirements.

7.3.3 Procedures

Once informed written consent was obtained, children underwent baseline assessment at the Mater Children's Hospital, Brisbane, by paediatric physiotherapists. Assessors were trained in a set testing protocol and had no involvement in the intervention. Following baseline assessment, randomisation to either the intervention group or the standard care group was performed by the Mater Mothers' Research Centre (MMRC) statistician and this was in the form of variable block randomisation (four per block). Assignment to group was concealed by using consecutively numbered sealed opaque envelopes prepared by a

member of MMRC external to the study team. Stratification occurred on the basis of cognitive abilities from the Stanford Binet with $IQ \leq 85$ / > 85 . Intervention commenced within one month of the children undergoing baseline measures. The intervention program occurred weekly for six weeks. Children were re-assessed on baseline measures within one month of program completion.

Intervention

The intervention program was based on a combination of traditional physiotherapy and task-oriented approaches. Traditional physiotherapy involves training an individual in essential age-specific gross and fine motor skills, as well as the fundamental motor abilities necessary to perform those skills. Task-oriented approach emphasises motor performance and incorporates cognitive approaches with attention directed towards specific aspects of a motor skill. There is evidence supporting the efficacy of both approaches amongst children with motor impairment such as developmental co-ordination disorder (Smits-Engelsman et al., 2013).

Intervention was group-based with three to four children per group. A trained paediatric physiotherapist led the intervention with the assistance of a physiotherapy student. Parents/carers facilitated as needed throughout the program and this may have been in the form of physical or motivational assistance or ensuring compliance with home programs. Sessions were structured and included the same key components each week, but activities within these components were progressed on a weekly basis.

In terms of the key or fundamental components, postural control and stability were addressed by targeting core stability and by incorporating it into functional balance. Core stability activities were progressed by position, with activities starting in long-sitting, then moving to sitting with feet free, then standing. Functional balance activities ranged from single leg stance games initially, such as kicking a ball, to walking heel-toe along an obstacle course towards the end of the program. Another key component was sensori-motor, including important aspects of position sense, tactile, eye movement and eye-hand co-ordination, and vestibular systems. Specific attention to upper girdle strength was a fundamental component of the program as well. Upper girdle strength activities became progressively more challenging each week. For instance, children initially performed commando crawl activities (abdomen in contact with floor), then transitioned on to

modified push-ups (partial support of body weight), followed by crab walks (further loading of elbow extensors/shoulder muscles to support body weight). Other key components that were included were paired activities, such as hand clapping games, and a fine motor element. Emphasis was also placed on an individual component with activities customised to each child's specific needs and goals. The weekly sessions were approximately one hour plus 20-30 minutes for home program explanation and parent discussion. The home program was updated weekly. It replicated each intervention session with similar components each week that were progressed in association with the intervention program.

Children were not prevented from accessing other therapies during the intervention period. Two children were attending occupational therapy whilst involved in the study.

7.3.4 Measurement tools

Primary outcome measure

Goal Attainment Scaling (GAS)

GAS was used to measure goal performance and to evaluate the effectiveness of the intervention program (King et al., 1999; Kiresuk & Sherman, 1968). GAS is a criterion-referenced measure of change at the level of the individual (King et al., 1999). It involves goal setting and identifying five possible outcomes for each goal. GAS enables grading of goal attainment and comparison across goals and children over time.

Prior to commencing the intervention and in partnership between an independent physiotherapist and parents/carers, three goals were identified for each child. We adhered to recommendations of King et al (1999) when writing these goals: relevant, understandable, measurable, behavioural, attainable and time-limited (King et al., 1999). We followed suggestions by having a different focus for each goal: goal one was 'action' focused, goal two was 'function' focused and goal three was 'performance' focused. Therefore, goals were individualized to the child, and by having the same three focus areas for all children (action, function, performance), group-based evaluation was enhanced. We utilized the original five-point scale developed by Kiresuk et al (table 7.1), with clinically equal intervals between scale levels (Kiresuk et al., 1994). The scale range was from "-2" (much less than expected outcome) to "+2" (much more than expected

outcome), with a score of “0” corresponding to expected level of performance. An example of GAS applied to one of our study children is shown in table 7.2. Goals were re-assessed at the completion of the intervention program and up to three trials were permitted when testing each goal. Bias was minimized by ensuring that the goals were written and assessed by an experienced physiotherapist who was not the physiotherapist leading the intervention. This independent physiotherapist, in collaboration with parents, performed the goal rating.

Table 7.1 - Goal Attainment Scaling – scaled levels

Attainment Level	Score	Description
Much less than expected outcome	-2	Performance that is expected to occur 7% of the time, ranging from regression to minor/no changes
Somewhat less than expected outcome	-1	Performance that is expected to occur 21% of the time and is somewhat less than anticipated for the treatment period
Expected level of performance by the end of the measurement period	0	Performance anticipated at the start of treatment for the designated measurement period and is expected to occur 43% of the time
Somewhat more than expected outcome	+1	Performance that is expected to occur 21% of the time and is somewhat more improvement than expected for the treatment period
Much more than expected outcome	+2	Performance that is expected to occur 7% of the time and is uncommon as significant more improvement than expected occurred during the measurement period

Kiresuk TJ, Smith A, Cardillo JE. Goal attainment scaling: Applications, theory, and measurement: Hillsdale NJ Erlbaum Assoc.; 1994.

Table 7.2 - Example of Goal Attainment Scaling for study child

Attainment Level	Score	1. Action	2. Function	3. Performance
Much less than expected outcome	-2	Stands on 1 leg with light assistance to maintain balance.	Uses palmar grasp to write some letters of name with verbal and visual cueing.	Occasional turn-taking when participating in group activities for 1 hour, verbal cueing required.
Somewhat less than expected outcome	-1	Stands on 1 leg for approximately 2 seconds with poor stability.	Uses palmar grasp to write all letters of name with verbal and visual cueing.	Turn-taking 25% of the time when participating in group activities for 1 hour, verbal cueing required.
Expected performance by the end of the measurement period	0	Stands on 1 leg for approximately 4 seconds with stability.	Uses dynamic tripod to write all letters of name with verbal and visual cueing.	Turn-taking 50% of the time when participating in group activities for 1 hour.
Somewhat more than expected outcome	+1	Stands on 1 leg for approximately 6 seconds with stability.	Uses dynamic tripod to write all letters of name with visual cueing.	Turn-taking 75% of the time when participating in group activities for 1 hour.
Much more than expected outcome	+2	Stands on 1 leg for approximately 8 seconds with stability.	Uses dynamic tripod to write all letters of name independently.	Consistently takes turns with other children when participating in group activities for 1 hour.

Outcome score for each goal was converted into a single T-score calculated using the formula developed by Kiresuk et al (Kiresuk & Sherman, 1968), with the mean of a series of T-scores expected to converge to 50 with one SD corresponding to a change in score of 10. A score of 50 or more would indicate that goals were attained. Mean aggregate T-scores allowed facilitation of reliability analyses and comparisons across children, as well as a global assessment of children's performance (King et al., 1999). Additionally, T-scores enabled us to utilise GAS in conjunction with standardised outcome measures to determine associations.

Other outcome measures

Movement Assessment Battery for Children second-edition (MABC-2)

Motor co-ordination of the children was assessed using the MABC-2 (Henderson et al., 2007). This is a norm-referenced standardised test and consists of three components: manual dexterity, aiming and catching and balance. Scoring of the MABC-2 provides an overall percentile rank. Children are classified as having definite motor difficulties if they have a percentile rank at the fifth percentile or less. A percentile rank between the fifth and 15th percentile indicates borderline motor difficulties.

Measures of postural stability

Postural control and balance were assessed using the timed single leg stance (SLS) and lateral reach test. These outcome measures are functional, used frequently in the clinical context and have been applied to children with a history of ELBW (Burns et al., 2009).

A set testing protocol with standard instructions was used for SLS, lateral reach and standing long jump tests. Children were tested barefoot and were given three trials per side of the body with best performance recorded.

Single Leg Stance (SLS) test (seconds)

Timing commenced when the child lifted the nominated leg. The free foot was not permitted to touch the other leg/floor. Eyes remained open. Timing ceased when the nominated leg touched the floor or when the testing criteria were no longer satisfied.

Lateral Reach test (centimetres)

The child was required to stand in front of a wall with feet shoulder width apart and with the nominated arm raised to 90 degrees of abduction. The child then reached as far sideways as possible whilst maintaining balance and a fixed base of support. The child was not allowed to lean against the wall. The distance reached was measured as the difference between arm's length (at 90 degrees of abduction) and maximal lateral reach of the finger tip of the third finger (Bartlett & Birmingham, 2003).

Functional measure of limb strength

Standing Long Jump test (centimetres)

Standing long jump was used to assess functional lower limb strength and control. There is evidence supporting its reliability as a measure of explosive strength amongst four and five year old children (Oja & Jürimäe, 1997). The child stood with toes behind a marked

take-off line, crouched and jumped forwards as far as possible. The child had to land two feet together. The horizontal distance jumped was measured from the take-off line to the point of the child's body that landed closest to the starting point (Oja & Jürimäe, 1997).

7.3.5 Statistical analysis

Analysis was by intention-to-treat and was performed using SPSS version 22.0 (IBM Corporation, Armonk, NY, USA, 2013). Sample size was pre-determined by the RCT previously mentioned, with power based on pilot data that led to the RCT. The pilot data demonstrated an average increase of 4 points from baseline to post-intervention on the MABC-2 standard score. This represents approximately a 20% increase in the MABC-2 standard score from baseline. Therefore, assuming a modest increase in score in the standard care group of 0.5 points, and an average increase of 4 points with a common standard deviation of 4.4, 25 participants per group would be required.

Changes in GAS were evaluated as per Kiresuk et al (Kiresuk & Sherman, 1968). An overall GAS score was calculated for each child and this was converted into a T-score using the formula, $T = 50 + C(x_i)$, which is based on the original formula developed by Kiresuk et al (Kiresuk et al., 1994; Schlosser, 2004). 'C' is a constant depending on the number of scales, so in our case $C = 3.01$. x_i represents the summed attainment score for the three goals. If a child had an overall GAS score of "0" (attained expected level of performance), this would convert to a T-score of 50. Any T-score over 50 would mean that a better than expected outcome was reached. Additionally, a GAS mean T-score for the group was determined. Pearson correlation evaluated associations between GAS scores and the other measures. Statistical significance was set at 5% (two-tailed).

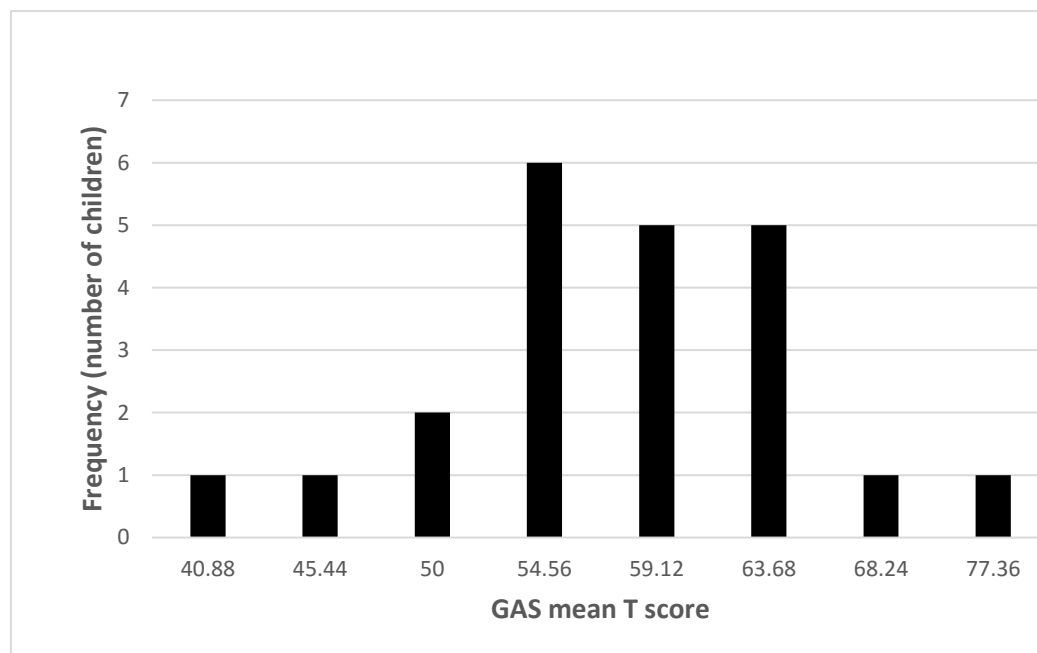
7.4 Results

7.4.1 GAS scores at re-assessment

Children in this study improved on GAS following intervention. GAS mean T-score of the group was 58.17 (SD=0.82), which meant that the group almost increased by one SD and exceeded the expected goal of "0" score (Figure 7.1). The range of GAS mean T-scores

was 40.88-77.36 with only one child reaching an improvement of more than two SD from the mean ($T=77.36$). One child did not reach the expected GAS mean T-score ($T=40.88$) and was one SD below the mean.

Figure 7.1 - Distribution of GAS mean T scores of the children after intervention (n=24)



7.4.2 Correlations between GAS scores and secondary outcome measures

GAS T-scores correlated moderately with overall MABC-2 percentile at re-assessment ($r=0.417$, $p=0.043$, $n=24$). A strong trend was found between GAS T-scores and the aiming and catching component of the MABC-2 ($r=0.398$, $p=0.054$, $n=24$), although this was not statistically significant. Higher GAS T-scores were associated with better MABC-2 outcomes in these domains. There were no correlations between GAS T-scores and scores on functional measures of postural stability and limb strength (p ranged from $p=0.172$ to $p=0.618$). However, there was a strong trend between GAS T-scores and lateral reach right ($r=0.402$, $p=0.057$, $n=23$), with higher GAS T-scores correlating with better performance on lateral reach right.

7.4.3 Relationship between GAS and gender

Females ($n=14$, $\text{mean}=60.75$, $\text{SD}=6.35$) scored significantly better on GAS than males ($n=10$, $\text{mean}=54.56$, $\text{SD}=8.04$) ($F=4.442$, $p=0.047$).

7.5 Discussion

Group-based physiotherapy intervention facilitated goal achievement for the ELBW children included in this study. The use of GAS proved to be an effective means of overall program evaluation as well. The significant personal gains made by the children over time were directly correlated with motor performance, indicating that improvements in motor skills promoted reaching set goals. Goal attainment was not related to functional postural stability and limb strength outcomes. Perhaps this was due to the goals being personalised to the individual and relating to more general motor demands, and so have a greater likelihood of being reflected in MABC-2 performance, whereas the functional measures were more task specific. Females not only scored significantly better than males on GAS, but performed more than one SD above the expected mean of 0. This finding of females performing better than males aligns with literature suggesting that extremely preterm males are at greater risk of poorer outcomes than females (Marlow et al., 2005). Possible reasons for the gender differences may be related to biologic vulnerability amongst extremely preterm males or adverse perinatal outcomes (Marlow et al., 2005).

Our study supports findings from other studies that have used GAS. Similar to these studies (Morgan et al., 2015; Steenbeek et al., 2007), we found that GAS was responsive and sensitive to incremental change amongst children. It is difficult to compare our study with previous research in relation to the combination of the model of intervention we used and our primary outcome measure. This is because other studies that have used group-based intervention in the paediatric setting have not included GAS and are too heterogeneous in terms of study population (Auld & Johnston, 2014; Pless et al., 2000; Watter & Bullock, 1989).

Strengths of this study include the utilisation of a primary outcome measure that is functional and meaningful to children and families at the individual level, reinforcing child and family centred care. Further benefits of using GAS include progress being related to

expected results, GAS is realistic, and goal setting may facilitate goal attainment through heightened motivation (Schlosser, 2004). Furthermore, GAS is closely aligned with all levels of the ICF framework. We also used GAS in association with other outcome measures, which not only added depth to our study but demonstrated where there may be some common bases for both goal attainment and motor performance. Importantly, our findings reinforce the clinical value of GAS. It is useful for clinicians who may have limited access to standardised tests, or when the standardised measure cannot be repeated within a short time frame.

Several limitations in this study can be identified. The intervention group was small, the intervention period was brief and perhaps the program was not as intense as other intervention programs. Unfortunately, it was not possible to extend the intervention period or prolong the time between GAS baseline assessment and re-assessment, so GAS was very much a short-term measure of change and not a reflection of longer term effects of intervention. Additionally, compliance with home programs was not measured in this study, which could have provided valuable information particularly if correlated with GAS. Finally, there are limitations associated with GAS itself, including the potential for bias, which could be related to goal setting, the level of training of the goal setter or assessor and through the rating process itself (King et al., 1999). However, in our study, care was taken to ensure that GAS was used as per recommendations and we employed strategies to minimise these sources of bias.

7.6 Conclusion

Mild neurodevelopmental impairments are common amongst four-year old ELBW children, therefore the role of intervention requires ongoing exploration. This study shows that group-based physiotherapy intervention does have short-term benefits. The children underwent intervention and improved their own performances and we showed that they reached their individual expected level of performance or better on specific goals using GAS. We can also conclude that GAS is a suitable tool to use amongst four-year old children with minimal/mild impairments. Consideration of the impact of group-based physiotherapy intervention on other neurodevelopmental outcomes will provide further management direction for the children included in this study.

7.7 Additional information

Study IV proved that group-based physiotherapy intervention in non-disabled ELBW children is beneficial and leads to personal growth. Hence, null hypothesis IV should be rejected.

CHAPTER 8

STUDY V Behaviour of 4-5 year old non-disabled ELBW children: outcomes following group-based physiotherapy intervention

It has been previously stated that prior to drawing conclusions and formulating recommendations regarding the management of non-disabled ELBW children at 4-5 years, it is necessary to consider the influence of intervention compared to best practice advice on other areas of development beyond motor and postural outcomes. Therefore, the final study investigated the longer term sequelae of these two approaches on behavioural outcomes of the children.

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Brown, L., Burns, Y. R., Watter, P., Gibbons, K. S., Gray, P. H. Behaviour of 4-5 year old non-disabled ELBW children: outcomes following group-based physiotherapy intervention.

8.1 Abstract

Background: Extreme prematurity or extremely low birth weight (ELBW) can adversely affect behaviour. Non-disabled ELBW children are at risk of behavioural problems, which may become a particular concern after commencement of formal education. This study aimed to explore the frequency of behavioural and emotional problems amongst non-disabled ELBW children at four to five years of age and whether intervention had a positive influence on behaviour. The relationship between behaviour and gender, and other areas of performance at five years, were also explored.

Methods: 50 four-year old children (born <28 weeks gestation or birth weight <1,000g) with minimal/mild motor impairment, were randomly allocated to intervention (n=24) or standard care (n=26). Intervention was six group-based physiotherapy weekly sessions and home program. Standard care was best practice advice. The Child Behavior Checklist (CBCL) for preschool children was completed at baseline and at one year post baseline. Other measures at follow-up included the Movement Assessment Battery for

Children second-edition (MABC-2); Beery Visual-Motor Integration Test 5th Edition (Beery VMI) and Peabody Picture Vocabulary Test 4th Edition (PPVT-4).

Results: The whole cohort improved on CBCL total problems score between baseline (mean 50.0, SD 11.1) and one year follow-up (mean 45.2 SD 10.3), $p=0.004$. There were no significant differences between groups over time on CBCL internalizing, externalizing or total problem scores. Males had higher total problem scores than females ($p=0.026$), although still performed within the 'normal' range. CBCL scores were not correlated with MABC-2, Beery VMI or PPVT-4 scores.

Conclusions: The behaviour of non-disabled ELBW children was within the 'normal' range at four to five years and both intervention and standard care led to improved behavioural outcomes. Behaviour was not related to performance in other developmental domains. As these children progress through school and are confronted with increasing challenges, behavioural problems may emerge.

8.2 Introduction

Extremely low birth weight (ELBW; birth weight < 1,000g) or extremely preterm (born < 28 weeks gestational age) children commonly exhibit behavioural problems at school-age (Hutchinson et al., 2013). Behavioural problems may include issues with self-regulation; difficulties with attention, sleep, eating and sensory sensitivity; and anxiety, depression and somatic problems (Arpi & Ferrari, 2013). It has been reported that over 50% of ELBW children have behavioural or social-emotional problems at age 30 months (Peralta-Carcelen et al., 2013). After school entry and with increasing age, behavioural issues may become more apparent due to further environmental demands challenging vulnerable abilities (Hayes & Sharif, 2009). The incidence of neurobehavioural impairment has been found to be as high as 71% amongst extremely preterm or ELBW children at eight years of age (Hutchinson et al., 2013).

At school-age, behavioural problems amongst ELBW or extremely preterm children may hinder academic functioning and performance. Ultimately, this may adversely affect quality of life (Hayes & Sharif, 2009). Therefore, adequate preparation prior to commencement of formal education is fundamental for these children, including those who are non-disabled. It is unclear whether non-disabled ELBW children are at similar risk of

behavioural problems as those with identifiable impairments. Teachers and parents often feel that ELBW children who have no major impairments and are otherwise able-bodied, lack school readiness (Roberts et al., 2011). Intervention may assist in preparing these children to cope with the demands of the classroom when they commence school, and in turn, may diminish the risk of school failure and the problems that could follow.

Identifying factors that are associated with behavioural problems may assist in providing more tailored intervention. It has been proposed that extremely preterm males are at greater risk of disability and learning difficulties (Marlow et al., 2005; O'Callaghan et al., 1996), as well as lower school-readiness levels (Oja & Jürimäe, 1997). Additionally, behavioural problems are more likely to occur when motor or cognitive difficulties are present (Hayes & Sharif, 2009).

Other neurodevelopmental domains that may be implicated alongside behavioural problems in this population include visual-motor abilities and language skills. It has been reported that ELBW children at five years of age perform significantly poorer on visual-motor co-ordination activities compared to term equivalent peers (Potharst et al., 2013). With increasing age, persistence of visual-motor discrepancies between these two cohorts has been found (Caravale et al., 2012). Visual-motor skills may be linked to functional skills, as well as handwriting skills and academic performance. Finally, very preterm and/or very low birth weight children have been found to have poorer language skills than term controls (Reidy et al., 2013).

We aimed to investigate the prevalence of behavioural and emotional problems amongst a cohort of four to five year old non-disabled ELBW children. We did this in conjunction with a larger study, a randomised controlled trial (RCT). This RCT explored the short term and longer term effects of group-based physiotherapy intervention compared to standard care on neurodevelopmental outcomes. In this current study, we aimed to determine whether the children who underwent intervention had fewer behavioural issues than the standard care children at one year post baseline assessment. It was hypothesised that the program would improve behaviour. We also aimed to explore if there was an association between behavioural and emotional problems and other factors at the one year follow-up assessment, including gender, motor co-ordination, visual-motor abilities and receptive vocabulary.

8.3 Methods

8.3.1 Study design

In the RCT, the children were recruited between July 2010 and February 2013. Assessment was conducted at the Mater Children's Hospital, Brisbane, by paediatric physiotherapists who had no involvement in the intervention or standard care of the children and were blinded to group allocation.

Children were stratified according to their cognitive abilities with $IQ \leq 85$ / > 85 . Randomisation was performed by the Mater Mothers' Research Centre (MMRC) in the form of variable block randomisation. Assignment to group was concealed by using sealed opaque envelopes prepared by a member of MMRC. Envelopes were identified by stratification group and consecutively numbered. Allocation to intervention or standard care was based on the order in which children were booked in for baseline assessment. Follow-up assessment occurred one year post baseline assessment.

The trial was approved by the Mater Health Services Human Research Ethics Committee and the Medical Research Ethics Committee of the University of Queensland and was registered with the Australian New Zealand Clinical Trials Registry (ACTRN12613000950763).

8.3.2 Participants

The characteristics of the children in this RCT have already been described (Brown et al., 2015). In brief, there were 50 participants born between May 2005 and November 2008. They had a birth weight of $< 1,000g$ or a gestational age of < 28 weeks and were managed in the Neonatal Intensive Care Unit at the Mater Mothers' Hospital, Brisbane, Australia. The children in this study will hereafter be referred to as ELBW. Children lived within one hour travel of the testing site and had not started formal education. Included children had attended the Mater Mothers' Hospital Growth and Development clinic for follow-up assessment at four years (corrected age) and had a score from the Neurosensory Motor Developmental Assessment (NSMDA) (Burns, 2014) of 9 to ≤ 12 (minimal to mild

deviation) and an IQ of > 70 (<70 corresponds to cognitive impairment) on the Stanford-Binet Intelligence Scales (Roid, 2003).

Children were excluded if they had significant congenital anomalies, neurological impairments, sensory impairments not corrected by aids, or if their family could not commit to the attendance requirements.

8.3.3 Intervention

Intervention was group-based with three to four children per group and combined traditional physiotherapy and task-oriented approaches. Traditional physiotherapy focuses on training age-specific gross and fine motors skills, as well as the fundamental motor abilities necessary to perform those skills. Task-oriented approach emphasises motor performance and incorporates cognitive approaches with attention directed towards specific components of a motor skill.

The intervention program consisted of weekly physiotherapy sessions for six weeks and these sessions were led by a trained paediatric physiotherapist (not involved in the assessment procedure). The sessions targeted each child's specific problems and were approximately one hour in duration plus 20-30 minutes for home program explanation and parent discussion. Home program and the intervention were progressed over time. Included activities addressed postural control and balance, sensori-motor skills and upper girdle strength.

The standard care group received 'optimal care' which was best practice advice and an informal booklet of general age-appropriate activities. Children in the intervention group also received this booklet at the completion of their intervention. Throughout the study period, contact was maintained with families of both groups via email. Children were not prevented from accessing other therapies during the trial.

8.3.4 Measures

Primary outcome measure

Child Behavior Checklist (CBCL) for Preschool Children

The CBCL/1 ½ -5 was used to determine the frequency of behavioural and emotional problems (Achenbach & Resorla, 2000). The parents of each child completed the CBCL questionnaire at baseline and one year follow-up assessment. Validity and reliability of the problems scales of this test have been reported (Achenbach & Resorla, 2000).

The CBCL assesses demographic details and provides a rating of 99 problem items on a three point scale. Problem items are converted into syndrome scale scores which can be grouped to calculate internalizing and externalizing T scores. T scores for internalizing and externalizing can be classified as borderline range (score of 60-63; or 83rd to 90th percentile), clinical range (score above 63; above the 90th percentile) or normal (score below 63; less than the 83rd percentile). Finally, a total problems score is determined and has a corresponding T score, which is classified as borderline, clinical or normal, with the same percentile cut-offs as per internalizing and externalizing T scores.

Other outcome measures (performed at one year follow-up assessment)

Movement Assessment Battery for Children second-edition (MABC-2)

MABC-2 was used to assess motor co-ordination (Henderson et al., 2007). This is a norm-referenced standardised test and consists of three broad categories: manual dexterity, aiming and catching and balance. Scoring of the MABC-2 provides an overall percentile rank. Children are classified as having definite motor difficulties if they have a percentile rank at the fifth percentile or less. A percentile rank between the fifth and 15th percentile indicates borderline motor difficulties.

Beery Visual-Motor Integration Test 5th Edition (Beery VMI)

The short form of the Beery VMI was used to test for visual-motor deficits (Beery et al., 2004). High reliability and validity for the Beery VMI has been reported. This is a norm-referenced test, with a standard score of 100 corresponding to 'normal' and SD 15.

Peabody Picture Vocabulary Test 4th Edition (PPVT-4)

PPVT is an individual intelligence test (Dunn & Dunn, 2007). This norm-referenced standardised test measures an individual's receptive (hearing) vocabulary for Standard English and provides a quick estimate of verbal ability and scholastic aptitude. Reliability and validity for this test is high. Raw scores are converted into standard scores with a

mean of 100 and SD 15. The PPVT consists of sets of items presented in order of increasing difficulty.

8.3.5 Statistical analysis

Sample size calculations were performed using pilot data (n=9) results on the MABC-2. The pilot data demonstrated an average increase of 4 points from baseline to post-intervention on the MABC-2 standard score. This represents approximately a 20% increase in the MABC-2 standard score from baseline. Therefore, assuming a modest increase in score in the standard care group of 0.5 points, and a common standard deviation of 4.4, 25 participants per group would be required. Sample size calculations for the current study were not based on CBCL results.

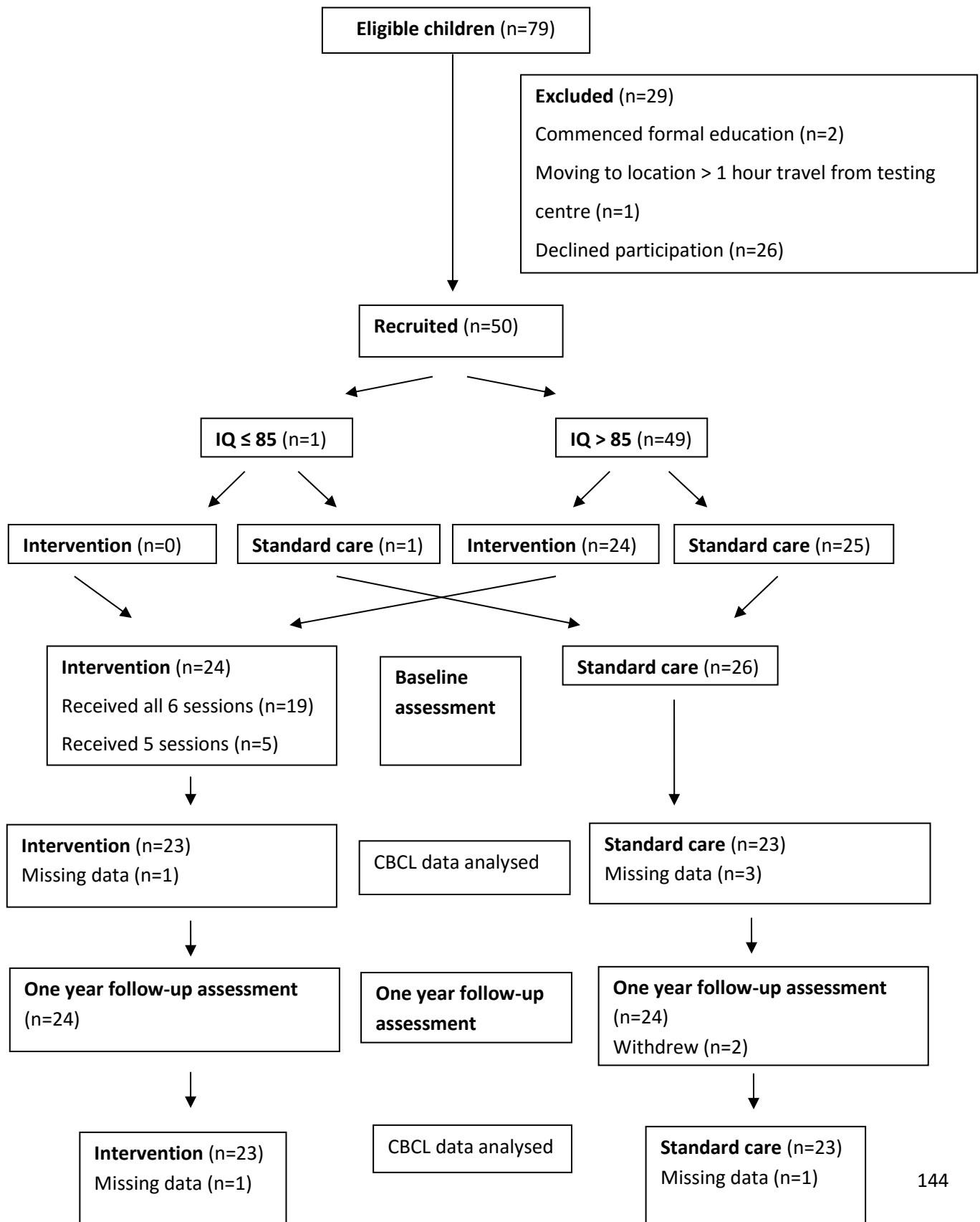
Analysis was by intention-to-treat and all analyses were performed using SPSS version 22.0 (IBM Corporation, Armonk, NY, USA, 2013). For normally distributed data, means and standard deviations (SD) are presented and for categorical data, percentages. When comparing between the groups, the continuous data was normally distributed so independent *t*-tests or analyses of variance were used. For categorical measures, chi-square or Fisher's exact test was used to determine statistical significance. Repeated measures analyses of variance were used for the primary outcome measure and paired *t* tests were used to calculate confidence intervals. Pearson correlation evaluated associations between CBCL scores and other areas of performance. Statistical significance was set at 5% (two-tailed).

8.4 Results

Fifty children completed baseline assessment (Figure 8.1). There were 24 children randomised to intervention and 26 to standard care. Forty-six out of the 50 children had baseline CBCL questionnaires completed by their parents (intervention group n=23; standard care group n=23). At one year follow-up assessment, 48 (96%) children were re-evaluated, 24 in the intervention group (mean corrected age 62.4 months, SD 2.3 months; 10 males) and 24 in the standard care group (mean corrected age 64.1 months, SD 2.9 months; 14 males). CBCL questionnaires were completed for 46 children (intervention group n=23; standard care group n=23). Although there were 46 CBCL questionnaires

completed at each time-point, not all were matched, reducing the number of paired reports to 21. Results for CBCL internalizing and externalizing syndrome scores, as well as total problem scores, are presented in terms of T scores (not raw scores).

Figure 8.1 - Flowchart of Child Behavior Checklists (CBCL) completed by parents



The details of the educational history of the study children indicated that at the one year follow-up assessment, 17 of the children were in preschool (education pre commencement of formal education) and 28 had commenced their first year of formal education (details for one child missing).

8.4.1 Whole cohort – CBCL

For all scores, the cohort mean performance was in the ‘normal’ range at baseline and one year follow-up assessment (Table 8.1). Results presented in Table 8.1 are based on the total cohort at each time-point.

Table 8.1 - Comparison of Child Behavior Checklist T score results of whole cohort over time

CBCL score	Baseline (n=46)	1 year follow-up (n=46)
Internalizing, mean (SD)	51.1 (10.6)	48.0 (11.2)
Internalizing, range	33-71	29-67
Internalizing clinical range, n (%)	7 (15)	5 (11)
Externalizing, mean (SD)	48.6 (12.0)	43.7 (10.1)
Externalizing, range	28-86	28-73
Externalizing clinical range, n (%)	5 (11)	2 (4)
Total problems, mean (SD)	50.0 (11.1)	45.2 (10.3)
Total problems, range	29-76	28-66
Total problems clinical range, n (%)	6 (13)	4 (9)

Note: T scores 60-63 (83rd – 90th percentile) = borderline range (below = normal, above = clinical range).

When the cohort with the number of available 'pairs' (n=42) was analysed using a paired *t* test, the results showed a significant change in total problem score, indicating improvement (mean difference 4.12, SD 8.6, *p* = 0.004; baseline mean 49.57, SD 11.3; one year follow-up mean 45.45, SD 10.5). However, the whole cohort was still classified as 'normal' at both time-points.

8.4.2 Changes between groups from baseline assessment to one year follow-up assessment – CBCL

There were no differences between groups on internalizing, externalizing or total problem scores over time (Table 8.2). Children in both groups improved in behavioural scores over time, although this only reached significance in the standard care group (internalizing *p* = 0.016, externalizing *p* = 0.016, total problem *p* = 0.003).

Table 8.2 - Comparison of Child Behavior Checklist T score results between groups over time

Group	Baseline, mean (SD) <i>Intervention n=20;</i> <i>Standard care n=26</i>	1 year follow-up, mean (SD) <i>Intervention n=23;</i> <i>Standard care n=23</i>	Mean (95% CI) difference between time-points for each group <i>Intervention n=19</i> <i>Standard care n=23</i>
Internalizing			
<i>Intervention group</i>	49.8 (12.1)	48.5 (12.1)	-1.2 (-4.7 to 7.1)
<i>Standard care group</i>	52.1 (9.4)	47.6 (10.4)	-4.1 (0.8 to 7.3)
Externalizing			
<i>Intervention group</i>	49.9 (13.8)	43.9 (11.0)	-4.9 (-0.7 to 10.5)
<i>Standard care group</i>	47.6 (10.5)	43.5 (9.4)	-4.1 (0.9 to 7.3)
Total problems			
<i>Intervention group</i>	49.6 (11.9)	45.4 (10.7)	-3.8 (-1.5 to 9.1)
<i>Standard care group</i>	49.9 (10.6)	45.0 (10.1)	-4.4 (1.6 to 7.1)

Note: Mean difference between time-points for each group based on number of available 'pairs' of data.

8.4.3 Relationship between gender and CBCL scores at one year follow-up assessment

When considering the whole cohort and the effect of gender, there was a significant difference in total problem scores between males and females at one year follow-up assessment, with higher scores amongst males (Table 8.3). There were no significant differences between males and females on internalizing and externalizing scores.

Table 8.3 - Gender effect of whole cohort on Child Behavior Checklist T score results at 1 year follow-up

Gender	Internalizing mean (SD)	Externalizing mean (SD)	Total problems mean (SD)
Males (n=23)	51.1 (11.0)	46.0 (9.0)	48.6 (9.5)
Females (n=23)	45.0 (10.7)	41.4 (10.8)	41.9 (10.1)
Difference between genders	p = 0.06	p = 0.117	p = 0.026

8.4.4 Correlations between CBCL scores of whole cohort and other areas of performance at one year follow-up assessment

Means and standard deviations for the whole cohort on the MABC-2, Beery VMI and PPVT-4 were within the normal range. When considering individual performances on these assessments at the one year follow-up point, 24 children had a percentile rank on the MABC-2 corresponding to borderline motor difficulties. On the Beery VMI, one child performed in the low range, whilst 15 performed below average. However, on the PPVT-4, all children performed within the average range. There were no significant correlations between CBCL score of the whole cohort and MABC-2 percentile (Table 8.4) or MABC-2 category standard scores (data not shown). Likewise, there were no correlations between CBCL scores of the whole cohort and Beery VMI standard score or PPVT-4 standard score (Table 8.4).

Table 8.4 - Correlations between Child Behavior Checklist T scores of whole cohort & other areas of performance at 1 year follow-up

	MABC-2 % (n=48)	Beery VMI SS (n=46)	PPVT-4 SS (n=46)
Mean (SD)	24.5 (25)	98 (6)	113 (27)
Internalizing	r=0.130 (p=0.389)	r=-0.078 (p=0.605)	r=-0.075 (p=0.621)
Externalizing	r=0.167 (p=0.268)	r=-0.161 (p=0.286)	r=-0.038 (p=0.804)
Total problems	r=0.146 (p=0.335)	r=-0.171 (p=0.257)	r=-0.080 (0.596)

8.5 Discussion

The current study found that the behaviour of our cohort of non-disabled ELBW children at four to five years of age was, on the whole, within the 'normal' range. This finding is contradictory to what has been reported in other studies (Hayes & Sharif, 2009; Hutchinson et al., 2013; Peralta-Carcelen et al., 2013) where a general ELBW population was considered, rather than just the non-disabled group. Also, we anticipated that even if behavioural problems were not yet evident at baseline assessment, then problems were likely to become more apparent at the one year follow-up mark following commencement of formal education for some children. However, this was not the case. The small, but significant, improvement in CBCL scores over the year suggests that further exploration of the effects of intervention and advice are warranted.

It is possible that as not all children had started formal education, behavioural issues in this cohort may emerge later as the challenges encountered by these children increase as they progress through school (Hayes & Sharif, 2009). A possible contributing factor to positive behavioural outcomes may be due to an increased interaction between parents and their children in both groups during the study period and perhaps this was reinforced by the regular email communication with parents. A similar outcome was found by

Huhtala et al, who reported that their cohort of very low birth weight children at three years of age did not have more behavioural problems than their full-term peers (Huhtala et al., 2012).

In terms of the impact of intervention, it appears that the children in our study benefited from both group-based physiotherapy and best practice. As far as we are aware, our group-based physiotherapy program for four year olds born extremely preterm or ELBW is the first of its kind, therefore we are unable to draw from other studies for comparative purposes. In our study, even though there were no differences between groups on behavioural outcomes, it could be suggested that both intervention and compliance with best practice advice contributed to the children performing within the 'normal' range at the one year follow-up assessment. In both groups, all CBCL scores were lower at follow-up, indicating that behaviour had improved. However, changes only reached significance in the standard care group. Additionally, interpretation must be guarded given that overall, the children were within the 'normal' range at the two time-points in both groups.

Our finding that males performed more poorly on behavioural testing is consistent with other studies of extremely preterm children (Marlow et al., 2005; O'Callaghan et al., 1996; Oja & Jürimäe, 1997). Male gender has been found to be a risk factor for poorer outcomes, and this is evident in this non-disabled group.

Interestingly, this study showed that behaviour was not related to other neurodevelopmental domains. Behaviour scores did not correlate with motor scores at one year post baseline. Ongoing analyses have indicated that although the overall motor performance of this cohort remained within the 'normal' range over time, motor difficulties became more pronounced with a decline in mean MABC-2 percentile and increase in the number of individuals performing in the borderline range for motor difficulties (personal communication). However, in the current study, behaviour did not follow the same pattern. Therefore, behaviour must be more robust and enhanced, at least in the short term, by intervention/best practice advice, coupled with little exposure to the challenges of formal education.

Visual-motor abilities and language skills also did not correlate with behaviour. On the Beery VMI, although the cohort, at large, performed within the normal range, nearly a third

of children performed below average. These findings are consistent with MABC-2 outcomes at the one year follow-up, suggesting a link between these areas of performance. On the PPVT-4, all individuals had receptive language skills within the average range. This is an important finding as performance on the PPVT-4 is indicative of a child's linguistic skills and cognitive level and is therefore useful in the context of school readiness (Dunn & Dunn, 2007). In summary, perhaps there are other factors linked to behaviour in this population, or that emerging challenges and comparison against larger school-based cohorts are yet to compound their effects.

One of the key strengths of our trial is that it is the first study to explore the impact of group-based physiotherapy intervention compared to standard care on a range of neurodevelopmental outcomes at an important time-point for non-disabled EBLW children. Furthermore, we have highlighted that both intervention and compliance with best practice advice may promote favourable behavioural outcomes, at least in the relatively short term.

In terms of limitations, we only used one key measure to assess behaviour. Perhaps, using additional measures that explore different aspects of behaviour would have added more depth to our study. Another factor was the relatively small cohort, which may limit the generalisability of our findings.

8.6 Conclusion

The non-disabled ELBW children in our study had fewer behavioural problems at four to five years of age than expected. Both intervention and standard care appeared to have a positive influence on behaviour. We know that non-disabled ELBW children are at risk of behavioural problems, therefore, ongoing follow-up of these children at an older age would be useful to explore any behavioural changes associated with ongoing challenges. Also, consideration of other factors that may be linked to behaviour would be beneficial. Further studies are needed that explore optimal treatment practice, frequency and length of intervention and role of formal monitoring. Addressing these issues would assist in optimising outcomes for this population.

8.7 Additional information

Following the outcomes of study V, null hypothesis V should be accepted as the behaviour of 4-5 year old non-disabled ELBW who underwent intervention was comparable to that of the children who received standard care. In fact, the behaviour of all the children at the one year follow-up was better than anticipated.

CHAPTER 9

DISCUSSION

9.1 Summary of findings and implications

This research found that, overall, non-disabled extremely preterm or ELBW children have low average performance at four and five years of age. There was a wide range of results amongst these non-disabled ELBW or extremely preterm children in all areas of performance. Perhaps this variability provided a degree of masking of those individuals that did perform in the 'at risk' or clinical range and this must not be overlooked. Therefore, further exploration of the characteristics of our group was important, to assist in understanding their performance.

In terms of baseline motor performance, mean percentile rank of the whole group on the MABC-2 was 31% and the incidence of DCD was 30%. This finding was somewhat surprising as performance was higher than anticipated and better than what is reported in the literature (Zwicker et al., 2013), although our group only included non-disabled ELBW children, rather than a general group of ELBW children. Zwicker et al reported that 42% of their group of four to five year old VLBW children developed DCD, whilst Dewey et al reported that 64% of five year old ELBW children had DCD (Dewey et al., 2011). The finding that our non-disabled children who met the DCD criteria had poorer postural stability compared to those children who did not meet this criteria, is consistent with previous studies that have reported on the co-existence of altered postural muscle activity and DCD (Johnston et al., 2002).

Our research showed that there were initial improvements in motor scores following both intervention and best practice advice. Despite these short term gains, over the longer term, motor scores declined although were still within the normal range, albeit at the lower end. This trend is consistent with other studies that have found that motor difficulties persist amongst non-disabled ELBW children (Burns et al., 2009; Goyen & Lui, 2002, 2009). Interestingly, the whole group continued to make gains on postural stability and lower limb strength measures throughout the 12 month follow-up period, indicating

functional improvements in the children's performance as a result of intervention, adherence with best practice advice and maturation. These personal functional gains were not enough to maintain age expected improvements over the follow up period and despite the improvements, the children are still likely to be at risk of postural stability issues in adolescence (Burns et al., 2008; Burns et al., 2009).

Behaviour of the whole group at baseline was within the normal range according to mean performance of the group on the CBCL, although between 11-15% of children had a score within the clinical range. As the children had not yet commenced formal education at this point, we expected that with some children entering school during the study period, behavioural problems would become more apparent and align with findings in the literature (Hayes & Sharif, 2009).

The children actually had fewer behavioural problems at the one year follow-up mark, based on mean performance on the CBCL. This finding of a lack of behavioural issues is contrary to other ELBW studies (Hayes & Sharif, 2009; Hutchinson et al., 2013; Peralta-Carcelen et al., 2013), although the other studies were based on the general ELBW population and not just the non-disabled. It may well be that the milder motor problems in our non-disabled group are paralleled by less severe behavioural problems. It is likely that once the group of non-disabled ELBW or extremely preterm children progress further through formal education and are confronted with more challenging cognitive processes and increased environmental demands, behaviour will follow a similar pattern to motor performance and more problems will emerge. It is well recognised that attention problems are more prevalent amongst school aged children born preterm compared to age-matched term peers (de Kieviet et al., 2012). Brogan et al reinforced this finding, reporting that very preterm school aged children had significantly higher inattention scores than term equivalent peers (Brogan et al., 2014). In this way, perhaps motor decline is a marker to monitor behaviour.

Our research did not find a relationship between behaviour of non-disabled ELBW children at five years of age and motor co-ordination, visual-motor abilities or receptive vocabulary. Previous studies of ELBW children at five years of age have demonstrated poorer visual-motor co-ordination skills compared to term equivalent peers (Potharst et al., 2013). Additionally, poorer language skills amongst very preterm and/or very low birth

weight children have been found (Reidy et al., 2013). Therefore, we were interested to determine whether behaviour of our group of non-disabled ELBW children related to performance in other neurodevelopmental domains, but this was not the case.

Comparisons of the outcome between the intervention and standard care group, found that the non-disabled ELBW or extremely preterm children benefited from both intervention and best practice advice, particularly in the short term. It was rewarding to find that standard care led to such positive outcomes. However, parents of children in the standard care group were motivated to follow advice provided by the activity booklets, suggesting that, within this group, it was *compliance* with best practice advice that likely led to this outcome. For both groups, motor performance improved in the short term, but in the longer term, there was a decline with an increasing disparity between the non-disabled ELBW or extremely preterm children and age-equivalent test norms. However, mean motor performance within both groups was still in the low average range.

It was important to compare the groups on other areas of performance that target individual change and could demonstrate gains despite the decline in motor performance when compared against age expected norms. Both groups improved in postural stability and lower limb strength in the short and longer term, indicative of increased ability over time. This meant that there were no between group differences on postural measures. The use of the GAS, pre and post intervention, also targeted individual change and supported the achievement of personal gains in the short term. The results of the GAS showed that the intervention children improved at the expected level or beyond as a result of intervention. Use of the GAS emphasised how important it is for the child and family to know that the child is making gains, especially in areas that they recognise as challenging. This positive feedback is likely to support the child's ongoing desire to improve.

Behaviour of both groups also improved over the longer term, accounting for the lack of differences between groups. Although a number of factors may have contributed to such a desirable behavioural outcome, one possible reason could be related to an increased interaction between parents and their children in both groups as a result of involvement in the intervention or standard care. Vanderveen et al reported that intervention studies in which the parents played a key role resulted in some beneficial effects (Vanderveen et al., 2009).

When within group changes in motor and postural outcomes were analysed, there were both similar and differing patterns of change. For instance, the intervention and standard care children made significant postural and strength improvements, but the intervention group improved to a greater extent on these measures. These differences may have been related to the parental focus in each group. For example, in the intervention group, parents may have concentrated on the intervention components, which included postural control, whereas in the standard care group, parents perhaps focused on the general activity booklet.

Other factors and their possible impact on outcomes were considered throughout the various studies. Of particular note, the influence of gender was examined. A recurring theme in the literature was that male gender was a risk factor for poorer performance. In our studies, males had more behavioural issues than females at four and five years and were not as successful in attaining goals on the GAS. The finding that males performed more poorly than females is consistent with other studies of extremely preterm children (Marlow et al., 2005; O'Callaghan et al., 1996; Oja & Jürimäe, 1997) and perhaps highlights the need to monitor males more closely, even in the non-disabled ELBW group.

As a result of the studies we conducted, our findings contribute to existing knowledge about the non-disabled ELBW or extremely preterm population and provide some directions for best practice management of these children. We know that these children often present with mild impairments and if these impairments can be alleviated via group-based intervention or compliance with best practice advice, then this has the potential to minimise activity limitations and promote participation for these children. Optimising performance of these children at four to five years of age is particularly important as it is a critical time-point for these children with the commencement of formal education. However, due to the ongoing nature of these impairments, although often regarded as minimal or mild, ongoing monitoring of these children is important and highly recommended. Our findings can be applied to the clinical setting to guide staff in managing non-disabled ELBW or extremely preterm children but also have relevance to the wider community including school teachers and parents.

9.2 Strengths of the study series

Strengths of the study series have been identified within the individual studies but will be summarised here. Firstly, this research used a range of outcome measures of both a quantitative and qualitative nature. Use of a number of outcome measures provided information about multiple areas of performance and was also more inclusive of all components of the ICF framework. These outcome measures had applicability to the child, parent and therapist, and could be easily applied to the clinical setting.

Another strength of the study series is that all studies had tight inclusion criteria. Comparisons were made between those children who participated in the studies and those eligible children who did not participate. There were no significant differences between groups in terms of perinatal and social characteristics or motor performance. This reduced bias means that the results of the studies are representative of non-disabled ELBW or extremely preterm children at four to five years of age but not necessarily to the total population of ELBW or extremely preterm children.

Furthermore, there was a high retention rate in the studies, with only two children not returning for the one year follow-up assessment. This strengthens the generalisability of the study findings but also reinforces that best practice advice can be beneficial when compliance is maintained and support provided.

Additionally, no previous research has explored the impact of group-based physiotherapy amongst non-disabled ELBW or extremely preterm children at four years of age. Therefore, our RCT was the first of its kind in this population. The many advantages of group-based intervention have already been discussed, as well as the significance of intervening at this critical time-point. Most importantly, this intervention approach contributed to short term motor improvements, as well as postural, functional and behavioural gains that were maintained one year later. Furthermore, evaluating the effectiveness of intervention leads to justification of programs and informs cost effective management.

Finally, both intervention and best practice advice required parents to play an active role and therefore incorporated an education component. This perhaps provided parents with

insight into their child's difficulties and strengths resulting in increased levels of activity and participation, enabling them to support their child more appropriately. This supports the important role of involving parents in the care of their child and the possible benefits amongst preterm children has been reported in the literature.

9.3 Limitations of the study series

Test selection issues have already been acknowledged as a limitation in this research. In particular, this relates to the use of the MABC-2. The MABC-2 is not designed to be used as a pre/post intervention tool despite being used as such in the literature. It also allows 'best single performance' and thus favours children with motor deficit as they may be able to perform one acceptable performance but lack the ability to repeat it. However, the MABC-2 has been used in previous studies (including the pilot study that led to the current study series), is recognised as a gold standard tool in the identification of children with DCD, and in the absence of another tool, it was deemed to be the most suitable for measuring motor performance.

A further limitation relates to the group-based physiotherapy program that was utilised in the intervention group. It could be argued that the six week block was perhaps too brief to expect major between group differences and that a longer intervention period, as per previous studies, may have led to more desirable outcomes amongst the intervention group. However, due to time constraints and practicality of operation, the six week time-frame was the best available option. Another issue associated with the intervention group is that there was no measure of compliance with home exercise program and that this may have further informed the results. Although this issue was considered, it was decided that reliability would have been questionable and it would have been difficult to measure accurately.

Lack of a control group of non-disabled ELBW or extremely preterm children was a limitation in the study series as well. Use of a strict control group may have enhanced the effect of the intervention program as the use of the informal activity booklet possibly influenced the natural developmental process of the standard care children. However, due to ethical reasons and the vulnerability of ELBW or extremely preterm children in general,

it was not appropriate to prevent them from receiving standard care. A term-equivalent control group would have perhaps added further depth to the research findings and reduced bias by ensuring assessors were blind. As there are often growth differences between ELBW or extremely preterm children and their term-equivalent peers, this could limit the degree to which the independent assessors were blind to group allocation.

The relatively small sample size is a limitation of the study series. Although utilisation of rigorous inclusion criteria and the low attrition rate can be seen as strengths in terms of extrapolating findings, generalisation of results should be done with caution.

9.4 Future directions for research

The findings of the study series add depth to current research of non-disabled ELBW or extremely preterm children and both challenges and builds on what is known about these children. It also provides a platform for directing future research initiatives. It is clear that mild neurodevelopmental impairments persist amongst this population, therefore, at the very least, ongoing screening is needed. This is especially important as these children progress further into formal education and become increasingly challenged. Monitoring of non-disabled ELBW or extremely preterm children would assist in early detection of problems so that resources and support services could be directed in the most appropriate and efficient manner. This would benefit the child and also society at large as it would be a more cost-effective approach.

In terms of intervention, this research has highlighted that intervention is complex and further evaluation of targeted interventions that have a lasting effect on the lives of non-disabled ELBW or extremely preterm children are needed. It may be that to achieve this outcome, longer intervention or repeated short periods of intervention are required. It would be helpful to consider the impact of intervention on behaviour in more detail, as well as the effect of intervention on other areas of development. Perhaps comparing group-based intervention to individual therapy would be useful as well.

There is a need to further investigate and understand causal factors for poorer outcomes amongst the non-disabled ELBW or extremely preterm children. More knowledge in this

area would ensure that the adverse sequelae of being born ELBW or extremely preterm could be minimised. For instance, exploration of the role of body weight would be useful. For example, if performance of these children is related to birth weight for gestational age, pattern of weight gain since birth, weight at the time of testing or postnatal morbidity.

9.5 Conclusions

This research in non-disabled ELBW or extremely preterm children at four to five years of age adds new knowledge to what is already known about this population. In particular, the children in this selective mildly affected group, performed at a higher level than reported elsewhere for ELBW children in general, although still at the lower end of the normal range and with 30% falling into the DCD category at baseline. However, it must be emphasised that findings from the study series also reinforce that challenges amongst these non-disabled children persist and are multi-faceted. When considering strategies to improve outcomes of non-disabled ELBW or extremely preterm children, both group-based intervention and compliance with best practice advice are effective for motor and functional performance at least in the short term and postural and behavioural outcomes in the longer term. However, these benefits may only be apparent if these children see themselves achieving personal growth and ongoing performance gains relative to their peers, as these factors are likely to impact on other aspects of development such as behaviour.

Although group-based therapy is perhaps somewhat superior when all factors are considered, in the current financial climate, advocating for compliance with best practice advice is the more economical option and still leads to positive outcomes. If intervention is not routinely offered to these children, ongoing monitoring throughout childhood and adolescents is strongly recommended. This proactive approach would ensure that available services are directed to where they are most needed, minimising the impact of impairments. As a result, activity and participation levels of non-disabled ELBW or extremely preterm children would be enhanced.

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APPENDICES

APPENDIX 1: Methodology

Appendix 1.1 Ethical clearances – Mater Health Services and University of Queensland (including approval of ethical extensions)

MATER HEALTH SERVICES HUMAN RESEARCH ETHICS COMMITTEE

1st April 2010

Associate Professor Yvonne Burns
C/- Ms Leith Poulsen
Growth and Development Unit
Mater Mothers' Hospital

Dear Associate Professor Burns

Re: Physiotherapy Intervention to Improve Motor Co-ordination, Postural Stability and Behaviour in Pre-school Children Born Extremely Preterm or with Extremely Low Birth Weight: A Randomised Controlled Trial Ref No. 1496C

I write to advise that the Mater Health Services Human Research Ethics Committee considers the above study to meet the requirements of the *National Statement on Ethical Conduct in Human Research* (2007) and has granted ethical approval for your research proposal. Please accept our very best wishes for the success of this study. *In all future correspondence with the Committee please quote the Mater reference number.*

Documents reviewed and approved include:

- Correspondence received 8th and 31st March 2010 and 1st April 2010 in response to Committee questions
- Consent Form, revised 1st April 2010
- Completed Mater Ethics Application Form
- Patient Information Sheet
- Staff Information Sheet
- Financial Costing Summary

This approval is valid until **01.04.13**. Please note the following conditions of approval.

- Any departure from the protocol detailed in your proposal must be reported immediately to the Committee.
- When you propose a change to an approved protocol, which you consider to be minor, you are required to submit a written request for approval to the Chairperson, through the Secretary. Such requests will be considered on a case by case basis and interim approval may be granted subject to ratification at the next meeting of the Committee.
- Where substantial changes to any approved protocol are proposed, you are required to submit a full, new proposal for consideration by the Human Research Ethics Committee.
- You are required to advise the Research Ethics Coordinator immediately of any complaints made, or expressions of concern raised, in relation to the study, or if any serious or unexpected adverse events occur.
- Under the *NHMRC National Statement on Ethical Conduct in Research Involving Humans*, research ethics committees are responsible for monitoring approved research to ensure continued compliance with ethical standards, and to determine the method of monitoring appropriate to each project. You are required to provide written reports on the progress of the approved project annually, the first report being due on **01.04.11** and finally on completion of the project. *(The Progress Report is located at <http://www.mater.org.au/Home/Research/Human-Research-Ethics-Committee.aspx>)*

or can be accessed through the Mater Intranet, Applications, Research Register then under the project name or alternately can be emailed to you). Please inform the Committee of publications, presentations at Conferences, education and quality improvement outcomes from this study. The Committee may also choose to conduct an interim audit of your research.

- Please be aware that all study procedures including follow up of participants and data analysis should be completed within the approval time frame or an extension should be requested.

Please contact the Executive Director in the participating hospital/hospitals prior to commencing of the study. To access medical records, for the purpose of this study, please provide a copy of this approval letter to the Corporate Health Information Manager. I would also be grateful if you could confirm the date of commencement. (All correspondence should be directed to the Mater Research Ethics Coordinator.)

Yours sincerely

Dr Helen Liley
Chairperson
Mater Health Services Human Research Ethics Committee



THE UNIVERSITY OF QUEENSLAND
Institutional Approval Form For Experiments On Humans
Including Behavioural Research

Chief Investigator: Dr Yvonne R. Burns

Project Title: Physiotherapy Intervention To Improve Motor Co-ordination, Postural Stability And Behaviour In Pre-School Children Born Extremely Preterm Or With Extremely Low Birth Weight: A Randomised Controlled Trial

Supervisor: Dr Pauline Watter

Co-Investigator(s): A/Prof Peter Gray, A/Prof Michael O'Callaghan, Ms Laura Brown, Dr Pauline Watter

Department(s): School of Health and Rehabilitation Sciences, Division of Physiotherapy

Project Number: 2010000505

Granting Agency/Degree: Mater Research

Duration: 31st December 2013

Comments:

Expedited review on the basis of approval from the Mater Health Services HREC, dated 01/04/2010.

Name of responsible Committee:-
Medical Research Ethics Committee

This project complies with the provisions contained in the *National Statement on Ethical Conduct in Human Research* and complies with the regulations governing experimentation on humans.

Name of Ethics Committee representative:-
Dr Dennis Taaffe
Deputy Chairperson
Medical Research Ethics Committee

Date: 23/4/2010

Signature:

Research & Research Training Division

DIRECTOR
Ian G Harris

The University of Queensland
Cumbræ-Stewart Building
Research Road
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Telephone 07 3365 3559
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Facsimile 07 3365 8383

Additional Notes to Ethics Approval

1. The clearance number should be quoted on the protocol coversheet when applying to a granting agency and in any correspondence relating to ethical clearance.
2. Clearance will normally be for the duration of the project unless otherwise stated in the institutional clearance form.
3. Adverse reaction to treatment by subjects, injury, or any other incidents affecting the welfare and/or health of subjects attributable to the research should be promptly reported to the Head of School and the Ethics Committee.
4. Amendments to any part of the approved protocol (including change of Investigator/s), documents, or questionnaires attached to the clearance must be submitted to the Ethics Committee for approval.
5. Unforeseen events that might affect continued ethical acceptability of the project must be immediately reported to the Ethics Committee.
6. Discontinuation of the project before the expected date of completion must be reported to the Ethics Committee, giving reasons.
7. **Advisers on 'Integrity in Research'**
As part of the University's commitment to the institutional statement, *Code of conduct for the Ethical Practice of Research (1990)*, and the NHMRC's *National Statement on Ethical Conduct in Research Involving Humans (2007)*, designated positions have been appointed as advisers on integrity in research. The Chairperson of each ethics committee acts in an advisory capacity to provide confidential advice on such matters as misconduct in research, the rights and duties of postgraduate supervisors, and procedures for dealing with allegations on research misconduct within the University. The contact number for the Chairperson of each ethics committee can be obtained from the Ethics Officer.
8. The Committee reserves the right to visit the research site and view materials at any time, and to conduct a full audit of the project.
9. It is the Committee's expectation, whenever possible, that work should result in publication. The Committee would require details to be submitted for our records.



10. Staff and students are encouraged to contact either the Ethics Officer (3365 3924), or Chairperson on other issues concerning the conduct of experimentation/research (e.g., involvement of children, informed consent) prior to commencement of the project and throughout the course of the study.

MATER HEALTH SERVICES HUMAN RESEARCH ETHICS COMMITTEE

23rd February 2012

Dr Yvonne Burns
Department of Physiotherapy
University of Queensland
St Lucia 4072

Dear Dr Burns

Re: Protocol Ref No. 1496C Physiotherapy Intervention to Improve Motor Co-ordination, Postural Stability and Behaviour in Pre-school Children Born Extremely Preterm or with Extremely Low Birth Weight: A Randomised Controlled Trial

The Mater Health Services Human Research Ethics Committee noted the request for extension of approval at its 22nd February 2012 meeting. Your approval has been extended to 22nd February 2015. Best wishes for the remainder of the study. Please continue to provide at least annual progress reports until the study has been completed.

You are reminded that this letter constitutes ethical approval only. You may also need to consult with the Research Governance Office to ensure the amendments comply with the existing authorisation that has been obtained.

Should you have any queries please do not hesitate to contact the office of the Research Ethics Coordinator on 3163 1585.

Yours sincerely



Ms Nikola Stepanov
Research Ethics Coordinator
Mater Health Services Human Research Ethics Committee

Research Ethics Coordinator Room 51-50-1 Level 3 Queensland Brain and Spinal Injury Centre
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THE UNIVERSITY OF QUEENSLAND
Institutional Human Research Ethics Approval

Project Title: Physiotherapy Intervention To Improve Motor Co-ordination, Postural Stability And Behaviour In Pre-School Children Born Extremely Preterm Or With Extremely Low Birth Weight: A Randomised Controlled Trial - 12/02/2014 - AMENDMENT

Chief Investigator: Dr Yvonne R. Burns

Supervisor: Dr Pauline Watter

Co-Investigator(s): A/Prof Peter Gray, A/Prof Michael O'Callaghan, Ms Laura Brown, Dr Pauline Watter

School(s): School of Health and Rehabilitation Sciences, Division of Physiotherapy

Approval Number: 2010000505

Granting Agency/Degree: Mater Research

Duration: 30th September 2014

Comments/Conditions:

Note: if this approval is for amendments to an already approved protocol for which a UQ Clinical Trials Protection/Insurance Form was originally submitted, then the researchers must directly notify the UQ Insurance Office of any changes to that Form and Participant Information Sheets & Consent Forms as a result of the amendments, before action.

Name of responsible Committee:
Medical Research Ethics Committee

This project complies with the provisions contained in the *National Statement on Ethical Conduct in Human Research* and complies with the regulations governing experimentation on humans.

Name of Ethics Committee representative:
Professor Bill Vicenzino
Chairperson
Medical Research Ethics Committee

Signature

Date

12 Feb 2014

PATIENT INFORMATION SHEET

Study Title: Physiotherapy intervention and outcomes in children born extremely preterm

Principal Investigator: **Assoc Prof Yvonne Burns**
Growth and Development Unit
Mater Mothers' Hospital
Telephone: 07 3163 8499
(Leith Poulsen, Growth and Development Unit Co-ordinator)
Email: y.burns@uq.edu.au

Co-Investigators: **Assoc Prof Peter Gray**
Mater Mothers' Hospital
Assoc Prof Michael O'Callaghan
Mater Children's Hospital
Laura Brown
Mater Children's Hospital

Your child is invited to participate in a follow-up study of motor co-ordination in children born extremely premature.

What is the purpose of the Research Project?

We wish to determine if a specifically designed program of physiotherapy intervention administered at the age of 4 years to children who were born extremely premature will result in benefits in postural stability, motor performance and functional outcome or if normal activities during the same period will be as effective in developing the child's skills.

Why is my child asked to be in the Research Project?

In recent years minor movement problems in extremely premature infants have been noted. The children are often clumsy and may have problems with jumping, hopping, catching a ball, tying shoelaces and with handwriting. These problems have been identified in up to 50% of extremely premature infants.

It has been shown that performance at 4 years is a good indicator for motor development in school age years. In Queensland, children are expected to start preparatory school (Prep) between 4-5 years of age, though many parents of extremely premature infants are concerned that their child is not ready for the demands of a 5 full days a week program of education.

A pilot study in 2008-09 indicated that a 6 week small group program of special activities (intervention) resulted in improvement in postural control and functional performance. However it is not known if the everyday activities and normal developmental processes in this age group would have resulted in the same outcome.

What does my child need to do to be in this Research Project?

The physiotherapy intervention program will take place at the Mater Children's Hospital. Following the routine 4 year Growth and Development Clinic visit, you will be asked if you and your child would be willing to be involved in this study. All the children will have a detailed movement assessment and the parents will be asked to complete a questionnaire regarding their child's performance. The children will be randomly divided into two groups. One group will attend a special program once a week for 6 weeks while the parents of the other group will be given information about development of 4 year old children. The children attending for the intervention program will be divided into groups of 4 each small group will attend a weekly structured small group program for 6 weeks, each lasting about one hour.

The program will be led by an experienced Paediatric Physiotherapist. The physiotherapy activity program will start with warm-up activities. This will be followed by activities to help with posture, balance, eye-hand co-ordination and arm strength. There will be the opportunity to identify and discuss specific concerns related to your child with the physiotherapist and to develop a program for implementation at home.

After completion of the program the parents will receive a list of general activities suitable for 4 year old children and will be asked to keep a diary of the child's activities and achievements over the subsequent 12 months. The parents of children who will not be attending the intervention program will also receive a list of general activities suitable for 4 year old children and will be asked to keep a diary of the child's activities and achievements over the subsequent 12 months. A Paediatric Physiotherapist will keep in regular contact by telephone.

Both groups of children will have a movement assessment before and after the period of intervention and then full reassessment 12 months from baseline assessment. In addition the Parents will be asked to complete questionnaires on competence, attention and behaviour of the child.

Is there likely to be a benefit to my child?

If the intervention program is successful, then your child's motor co-ordination and posture may be improved, which may have long term benefits during childhood. All the children will have detailed assessments and results will be available to the parents after the study program.

Is there likely to be a benefit to other children in the future?

A pilot trial did show some improvement in the children and therefore it is possible that this study may provide additional evidence of its value. If the program is shown overall to be beneficial, then it is hoped that it could be made available as standard management to the advantage of many premature children in the future.

What are the possible risks for my child?

None.

What are the likely things that could be an inconvenience for me or my child?

The only thing is the time taken for each of the assessments will be approximately 1 -1.5hours.

Will expenses be covered?

Parking costs and reasonable travel expenses will be covered on request.

What will be done to ensure the information obtained on my child is confidential?

All information obtained will remain confidential and will be kept in secure filing cabinets and on a secure computer. No identifying data will be released, except to health professionals at your request and with your approval. Only group data will be presented in any publications arising from this research.

Will I obtain the results of the assessments on my child?

The results of the assessments before and after the intervention program will be made available. A summary of the study's findings will be provided on request.

Participation in the study is entirely voluntary and if you do not wish to take part, the treatment of you child will not be affected.

You can decide to withdraw your child from this research project at any time.

If you have any concerns about the project you may contact Leith Poulsen, Growth and Development Unit Co-ordinator at any time on 07 3163 8849. This study has been approved by the Mater Health Services Human Research Ethics Committee. If you have any complaints or concerns, you may contact the Mater Research Ethics Coordinator on 07 3163 1585, who may contact the Patient Representative or Hospital Ethicist at her discretion.

PATIENT INFORMATION SHEET continued

Study Title: Physiotherapy intervention and outcomes in children born extremely preterm

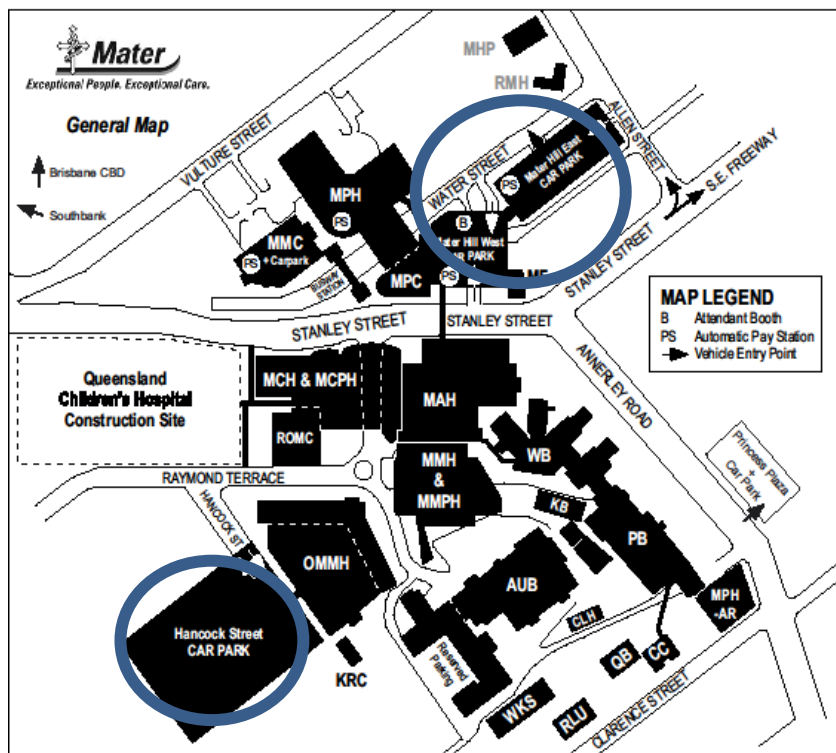
Principal Investigator: **Assoc Prof Yvonne Burns**
Growth and Development Unit
Mater Mothers' Hospital
Telephone: 07 3163 8499
(Leith Poulsen, Growth and Development Unit Co-ordinator)
Email: y.burns@uq.edu.au

Co-Investigators: **Assoc Prof Peter Gray**
Mater Mothers' Hospital
Assoc Prof Michael O'Callaghan
Mater Children's Hospital
Laura Brown
Mater Children's Hospital

Car Park Information

The closest car parks to MCH are Hancock Street car park and Mater Hill car parks (East and West). These car parks are circled on the map below.

If parking within the Mater Hospital car parks, you can request a prepaid parking ticket from the Physiotherapist at the time of your child's review. To exit the car park, insert the ticket into the machine.



LEGEND

MAH	Mater Adult Hospital
MCH	Mater Children's Hospital
MCPH	Mater Children's Private Hospital
MMC	Mater Medical Centre
MMH	Mater Mothers' Hospital
MMPH	Mater Mothers' Private Hospital
MPC	Mater Private Clinic
MPH	Mater Private Hospital
OOMH	Original Mater Mothers' Hospital

Contact Options

If you are happy to be contacted via email, please indicate this by providing us with your email address on the consent form. If you provide us with your email address, this will enable us to send you updates and new information via email.

CONSENT FORM

Study Title **Physiotherapy intervention and outcomes in children born extremely preterm**

Principal Investigator: **Assoc Prof Yvonne Burns**
Growth and Development Unit
Mater Mothers' Hospital
Telephone: 07 3163 8849
(Leith Poulsen, Growth and Development Unit, Co-ordinator)
Email: y.burns@uq.edu.au

Co-Investigators: **Assoc Prof Peter Gray**
Mater Mothers' Hospital
Assoc Prof Michael O'Callaghan
Mater Children's Hospital
Laura Brown
Mater Children's Hospital

I have:

- Read and understood the information sheet;
- Had any questions or queries answered to my satisfaction;
- Understood that the project is for the purpose of research and not for treatment;
- Understood that this study involves randomisation;
- Been informed that the confidentiality of the information obtained will be maintained and safeguarded;
- Given permission for access to the medical records of my child, for the purpose of this study;
- Been assured that I am free to withdraw consent for my child's participation at any time without comment or penalty and
- Agreed for my child to participate in the project.

Names & Signatures:

Child Name.....

Parent Name.....

Parent Signature.....

Date.....

Witness.....

Date.....

APPENDIX 2: Intervention outline

RCT INTERVENTION PROGRAM

REMEMBER: *STOP* ➡ *STEADY* ➡ *LOOK* ➡ *ACT!*

WEEK 1

Welcome/housekeeping

- introductions & briefing on program
 - 1 hour for 6 consecutive weeks
 - importance of being punctual (aim to arrive 15 minutes prior to commencement)
 - ensure breakfast/meal beforehand
 - individualised goal setting week 1
 - weekly HEP
 - email contact
 - parking tickets
 - photos - consent form
- toilets

1. WARM UP: Walk/run

- in a circle around cones
- use music - song 1 'I like to sing', I like to sing
- do: walking/jogging, stop/start work using music, change direction
- if children shy - get parents involved, shift focus to participation

2. POSTURAL CONTROL: Sit activity - deep core

- activities that involve reaching up with both arms just above shoulder level
- eg. long sitting on floor + doing fine motor task at a table (at shoulder height) such as building a tower, magnets (picking magnets up but also practising taking them off), playdough, balls in bucket



3. PAIRED ACTIVITIES: Sit & pass ball

- sitting on floor and throw ball to each other; use hoops on floor to indicate where child to sit (stick down); music to assist with variations to activity - song 7 'I like to sing', I like to sing (start/stop, direction change, pair swapping)
- eg. do in pairs using a square shape set-up, then swap pairs; or do in circle and change directions

4. UPPER LIMB: Commando crawl

- obstacle course - mat, tunnel, ramp, stairs
- child to carry toy in each hand from start to finish eg. army men (for army game), animal
- children to line up and wait for their turn
- ?music - song 4 'Watermelon', I like to sing



5. STATIC & DYNAMIC BALANCE: Kick a ball in SLS

- eg. kick a stationary ball between goals, have 2 teams of 2 - first team to 10 wins; or nudge small ball off cone, have a line of cones with balls on top, children to line up and wait for their turn (swap order)



6. SENSORY MOTOR ACTIVITIES: Eye tracking & copy me

- arms eg. up, out to side, in front, cross arms, one arm up and one arm forward
- legs eg. long sit, side sit, both knees up and feet flat, one knee up and one knee straight
- activity could be done whilst moving to another room

7. FINE MOTOR

- combined with postural control activity (see above)

8. WARM DOWN

- rocket stand on one leg

9. INDIVIDUAL/PARENT TIME

- GAS

- distribute - photo consent form, parking ticket

10. HEP

- Aim 1: To improve postural stability of trunk

→ long sit catch and throw

→ long sit plus do fine motor task at table

- Aim 2: To improve stability of upper trunk and shoulders

→ commando crawling exercises eg. races/relays, obstacle courses

- Aim 3: To improve ability to weight shift and maintain balance on 1 leg

→ kicking games - ball stationary

→ single leg stance musical statues eg. walk in a circle and when music stops, stand on one leg for as long as possible

→ tightrope walking

- Aim 4: To improve position awareness of body parts

→ Copy me games eg. Simon says, progress to copy me games with visual cue only

- Aim 5: To address child specific needs (as per NSMDA Ax)

*Useful website for behavioural issues, etc: raisingchildren.net.au

WEEK 2

1. WARM UP: Action song

- use music - song 2 'Hokey Pokey', Games and activity songs; song 1 'If you're happy and you know it clap your hands', More silly songs

2. POSTURAL CONTROL: Sit feet free

- sitting on adult chair or table
- eg. felt board activity; or throwing ball into basketball hoop



3. PAIRED ACTIVITIES: Stand & pass ball

- eg. ball kicking in pairs; or line ball; or children to stand in circle, Physio stands in middle and throws ball to child who then throws it back to Physio, initially Physio moves sequentially from one child to the next and then randomly
- children could number off whilst playing game

4. UPPER LIMB: Wall press

- use hands and feet to assist with positioning



5. STATIC & DYNAMIC BALANCE: Balance board

- use big dome



- boat ride analogy and singing 'row, row, row your boat'
- children sit on floor (in hoops stuck to floor) around dome
- intersperse rocky boat ride with ball throwing/catching to children sitting around dome

6. SENSORY MOTOR ACTIVITIES: Eye hand co-ordination & copy me hands

- hand positions: thumbs up, wrists up/down, guns, hands open/closed, thumb to index, index pointing, tent for lumbricals (open front door, back door, windows)
- eg. sit in hoops in circle; or could combine with balance board activity above ie. all children to do boat signals before boat ride



7. FINE MOTOR

- drawing - copying activity whilst sitting at table (feet stabilised)
- think about shoulder position, elbow support, forearm must remain on table, pencil grip (pencil between thumb and first two fingers), wrist extension
- each child to have clipboard with paper and pencil
- parent to draw, then child to copy
- eg. 'cross', V, H, T, O

8. WARM DOWN

- elephant/dinosaur walks
- eg. follow the leader; use music - song 2 'So many animals', Hi5

9. INDIVIDUAL/PARENT TIME: Read with me

- a book where your child can follow through the pictures of the simple story line whilst you are reading to them is a good way for them to develop a pattern of listening and to become aware of the sequence of events as well as the meaning of the story
- an indication that your child is involved in the story is when you notice how eager your child is to turn the page to find out what happens next

- try the local library for some books - those that have clear uncluttered illustrations/pictures associated with the story (picture story books) are best

10. HEP

- Aim 1: To improve postural stability of trunk
 - sitting feet free activities eg. finger painting, shaving cream on mirror, throwing/catching games, puzzles
- Aim 2: To improve stability of upper trunk and shoulders
 - wall push ups
- Aim 3: To improve dynamic sitting balance ie. the ability of the trunk to respond to destabilising movements
 - rocky boat ride whilst sitting on pillow and intersperse with throwing socks into basket, then combine activities
- Aim 4: To improve eye hand co-ordination
 - copy me hand positions; caterpillar games
 - 'copying' drawing task
- Aim 5: To address child specific goals (GAS) and needs (as per NSMDA Ax)
- Aim 6: To work on reading
 - picture story books - child to follow through the pictures of the story whilst parent reads to them

WEEK 3

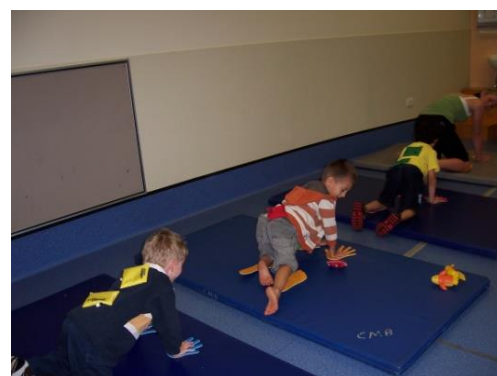
Introduce the blindfold and explain it will be used for an activity today

1. WARM UP: Marching

- children to pretend they are in a marching band
- use music - song 16 'I am a', I like to sing
- each child to have a musical instrument (eg. maraca, bells, drum, xylophone) and march around as a marching band
- stop music and get children to march to pattern 'left, left, left, left, right, left' whilst verbally saying it

2. POSTURAL CONTROL: 4 point kneel

- maintain neutral spine whilst keeping 1-2 bean bags on back
- use train analogy - each child to line up one behind the other and pretend they are a train carriage of a train
- practise weight shift - from side to side to help the train turn; then one front wheel up (hand up) and hold to change train lines followed by front wheel back down (hand down) then same side back wheel up (foot up) and hold to complete train line change followed by back wheel back down (foot down); then repeat train line change for other arm and foot
- use sounds 'toot toot'
- other ideas - ant or bubble wrap



3. PAIRED ACTIVITIES: Mirror actions

- transitional from supine → squatting → 4 point/prone → high kneel → standing
- use 1 x animal/position and children to copy - dead beetle (supine), chicken (squatting), star fish (prone), kangaroo (high kneel), emu (standing)
- initially, verbal and visual cue then only visual
- children can be doing actions in each position (don't have to freeze)
- have picture on wall of animals



4. UPPER LIMB: Chair push-ups

- legs on bolsters and children in 'wheel barrow' position
- children to keep walls of the tunnel up for a series of balls/trucks to pass through
- could also do as crab races with bean bag on tummy



5. STATIC & DYNAMIC BALANCE: Balance Beam

- mini obstacle course with connectable beam/slats, bridge and ladder
- use animals/vegies to nudge off
- take one child through obstacle course at a time (not heel toe at this stage); with ladder, step between rungs
- other children - either stand and wait their turn or they could be doing a rowing exercise (children in line with a long rod in their right hand and row as a team, then swap hands, then one in both hands)



6. SENSORY MOTOR ACTIVITIES: Find the shapes & vestibular activity

(a) Find the shapes

- have 4 x buckets each filled with something different eg. rice, beads, sand, cellophane, split peas
- have 4 of the same items in each bucket eg. spoon, peg, marble, block
- hold up one of the items in the buckets and ask the children to find it
- progress by occluding vision - use a box that has a hole in it and position it over the bucket



- children to rotate so that they have a turn of finding items amongst each of the different materials in the buckets

(b) Vestibular activity

- use rocket ride analogy - children to form a line; children to pretend they are rockets ie. rocket going up/down, to the side/other side; child at front to have blind fold on; ?stand on rocket picture
- Dora game - similar to pin the tail on the donkey with blindfold; spin child x 2 with blindfold on, then child sticks their piece on Dora

7. WARM DOWN

- indoor T-ball (just hitting ball) or cricket

8. INDIVIDUAL/PARENT TIME: Increase attention

- discuss task completion with parents ie. child carrying through a task from start to finish; repeatable task; progress by duration (2 minutes, then 3 minutes, then 4 minutes, etc.) eg. puzzle, putting something away

9. HEP

- Aim 1: To improve postural stability of trunk
 - 4 point kneel exercises involving weight shift eg. train concept, marble games, rolling ball to someone then stopping it when they roll it back, hands on bubble wrap
- Aim 2: To improve ability to weight shift and maintain balance on 1 leg
 - obstacle course
 - games involving walking on heels and walking on toes
- Aim 3: To improve sensory awareness
 - find the shapes games ie. hide objects in sand/rice/water with vision occluded and ask child to find a particular shape
- Aim 4: To improve eye hand co-ordination
 - bat and ball games
 - making necklaces - try using pasta and shoelace
- Aim 5: To address child specific goals (GAS) and needs (as per NSMDA Ax)
- Aim 6: To increase attention
 - task completion - progress by duration

WEEK 4

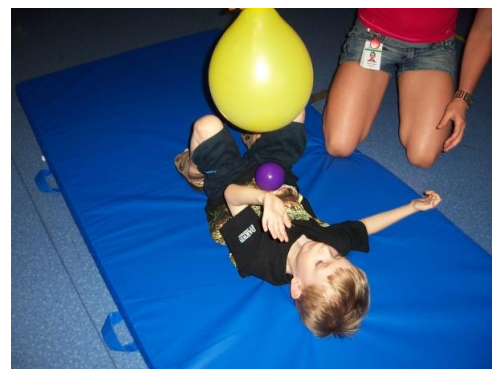
1. WARM UP: Jogging

- taking turns running an animal up to hoop
- 'rob the nest' game using big shell full of balls in middle and 2 teams of 2
- music - song 1 'It's a Playtime', Games and activity songs



2. POSTURAL CONTROL: Lying

- children positioned in crook lye
- children to keep small ball on stomach then single arm lifts (hit a suspended balloon)
- then leg slides (hit a ball)



3. PAIRED ACTIVITIES: Clap patterns

- initially child to copy 3-4 sequence pattern
- child to be in pair with parent and do same clap pattern throughout a whole clap song eg. individual clap then clap both hands with partner or individual clap then clap both hands with partner twice; child to practise pattern first with parent before adding in song; clap songs - 'Nicholas Picholas', 'Nobody likes me'
- clapping game involving clapping knees eg. clap hands together then clap knees whilst child sitting; child to practise pattern first then add in song; clap song - 'Who stole the cookies from the cookie jar', plus clap songs as above
- call out different colours and child has to put their hands on the correct colour hand prints (positioned around child)



4. UPPER LIMB: Theraband games

- fishing game and pulling fish in (forwards, backwards)



5. STATIC & DYNAMIC BALANCE: Step up backwards

- position bricks in a circle
- children to take turns walking through the circle backwards and stepping up and down bricks backwards - quiet steps
- other children - do fine motor task eg. practise drawing their family and house or stand and wait their turn



6. SENSORY MOTOR ACTIVITIES: Position awareness - all body

- transitional from supine → sitting → 4 point/prone/side sit → high kneel → standing
- use 1 x profession/position and children to copy - weight lifter (supine), a truck driver (sitting), a swimmer (prone) a boxer (high kneel) a ballerina (standing)
- initially, verbal and visual cue then only visual
- children can be doing actions in each position (don't have to freeze)



7. FINE MOTOR

- to be performed whilst waiting turn during static & dynamic balance task
- children to draw their family and house

8. WARM DOWN

- circles and figures of 8 eg. musical chairs; duck, duck, goose; soccer drill; running relay using cones so children running in figure of 8 pattern and bringing back piece of fruit each time; one child at a time
- music - song 14 'The dancing chicken', I like to sing

9. INDIVIDUAL/PARENT TIME: Tell me a story

- child to tell story eg. about their drawing or a story in a book
- the drawing or the story may make no sense, but it is the development of the child's imagination that is important

10. HEP

- Aim 1: To improve postural stability of trunk
 - lying on back and balance a ball on tummy +/- arm lifts and leg slides
- Aim 2: To improve ability to weight shift and to improve co-ordination of lower limbs
 - walking up steps backwards
 - games involving walking backwards around obstacles and cones
- Aim 3: To improve stability of upper trunk and shoulders
 - theraband activities
- Aim 4: To improve position awareness and to improve co-ordination of upper limbs
 - clapping games
 - copy games
 - caterpillar games
- Aim 5: To address child specific goals (GAS) and needs (as per NSMDA Ax)
- Aim 6: Story telling
 - child to tell parent a story eg. about their drawing or a story in a book

WEEK 5

1. WARM UP: Run stop run

- musical statues - children to run around room in a circle and freeze when the music stops
- music - song 1 'It's a party', Hi5
- red light/green light - one person is the 'stop light' and the rest try to touch him/her; at the start, all the children form a line away from the stop light; stop light faces away from the line of kids and says 'green light' at which point the kids move towards the stoplight; at any point the stop light may say 'red light' and turn around, if the kids are moving then they are out; play resumes when the stop light turns around and says 'green light'; stop light wins if all kids are out before any one touches him/her; otherwise, first kid to touch the stop light wins the game and then becomes the stop light

2. POSTURAL CONTROL: Standing

- standing basketball thrusts with both hands - high basketball ring; children to practise hopping (on foam squares) or bouncing ball before they shoot the ball
- balloon tapping with a baton held in both hands - 2 teams of 2

3. PAIRED ACTIVITIES: Cross patterns

- clap patterns involving crossing the midline - child to be in pair with parent and do same clap pattern throughout a whole clap song eg. individual clap then clap same hands with partner (ie. both clap right hands together so crossing midline); child to practise clap pattern first, then add in song; clap songs - 'Nicholas Picholas', 'Pat-a-cake, pat-a-cake, baker's man'
- clapping game involving clapping hands together then clap opposite hand to opposite knee while child sitting; child to practise pattern first then add in song; clap song - 'Who stole the cookies from the cookie jar'
- 'copy me' games involving crossing the midline when changing rooms eg. children to 'freeze' and copy physio ie. 1 arm forward, other across chest; 1 arm elevated, other touching opposite ear; 1 arm abducted, other hand on opposite knee; arms to side, 1 leg crossed in front of other

4. UPPER LIMB: Resist activity

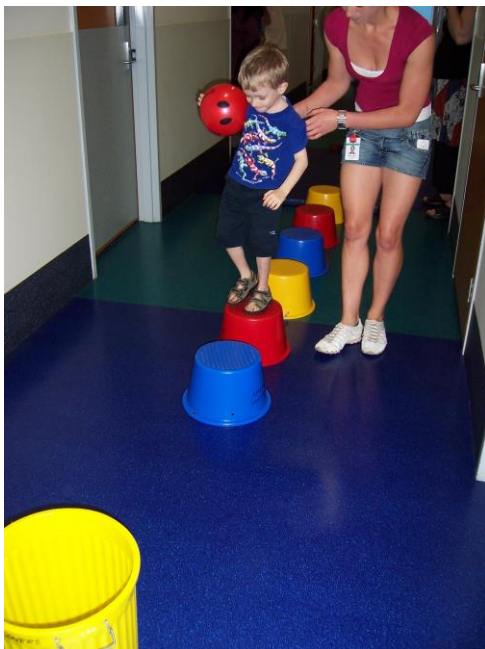
- crab walking over obstacles - up/down ramp (up ramp too tricky for some)

- tugowar
- prone with legs on bolsters and children in 'wheel barrow' position - children to build a tower (combine fine motor task)



5. STATIC & DYNAMIC BALANCE: Heel toe

- start with walking heel toe along a taped line on floor
- then progress to balance beam (stand beside child)
- children to hold ball and throw it in bucket at end then do bilateral jump off beam
- pretend there are crocodiles below so children have to be very careful not to fall off the bridge
- could use buckets too (thin mat underneath)



6. SENSORY MOTOR ACTIVITIES: Mr potato man hidden

- magician game - initially show children Mr. Potato man made up and then break him up and show children his different parts

- hide parts under a sheet (bright coloured) on the table and then ask the children to find a part eg. arm
- do 2 x children at a time

7. FINE MOTOR

- to be performed whilst doing upper limb resist activity
- build a tower

8. WARM DOWN

- tiggy

9. PARENT TIME: How to progress

- as per HEP

10. HEP

- Aim 1: To improve postural stability of trunk
 - basketball thrusts
 - balloon tapping with a baton held in both hands
- Aim 2: To improve ability to weight shift and to improve co-ordination of lower limbs
 - walking heel toe on a line, heel walking, walking on toes
 - hopping games
- Aim 3: To improve stability of upper trunk and shoulders
 - crab races
 - tugowar
- Aim 4: To improve position and sensory awareness and to improve co-ordination of upper limbs
 - clapping games involving crossing the midline
 - magician games using various parts of a toy
- Aim 5: To address child specific goals (GAS) and needs

WEEK 6

1. WARM UP: Star jumps

- practise star jumps first
- then play music, get children to walk/walk backwards/run/run on tip toes/skip/gallop, each time the music stops the children must do 5 x star jumps and then sit
- music - song 18 'A ram, sam, sam', More Silly Songs

2. POSTURAL CONTROL: PC during activity

- prone with legs on bolsters and children in 'wheel barrow' position - caterpillar game using party pop material or throwing animals into buckets
- crook lye - children to keep small ball on stomach then single arm lifts then single leg slides via bubble popping
- sitting on chair with feet free - try to bounce therapy ball as high as can
- consider stations using above tasks
- jump rope (helicopter game)
- 'boinger' races

3. PAIRED ACTIVITIES: Copy me

- 'copy me' games involving cross patterns (hand, arm and leg patterns)
- use boat analogy - first row the boat standing up and crossing the midline, then throw the fishing line in so crossing the midline with upper limbs and lower limbs (stride stance), then half kneel to grab the fish (try one side but jumps to other side so swapping from one side to the other), then high kneel to move the fish from the ground up into the bucket so crossing midline again (do multiple times as more than one fish), then long sit to row back to shore, then cycle legs to help get back as arms are sore
- use music - song 8 'There's a hole in the bottom of the sea', More silly songs
- ?do up pictures or make standing waves

4. UPPER LIMB: Increase repeats

- crab races over obstacles whilst keeping beanbag on tummy; interchange with commando crawling
- tugowar
- theraband



5. STATIC & DYNAMIC BALANCE: SLS move ball to side, bhd

- walking along balance beam then nudge balls off the top of cones
- hopscotch

6. SENSORY MOTOR ACTIVITIES: Integrate all senses (shape, feel, hear, see)

- combine with fine motor - drawing activity
- think about shoulder position, elbow support, forearm remains on table, pencil grip (pencil between thumb and first two fingers), wrist extension
- child to copy over their name first
- then child to draw first letter of their name then add the other letters - child could write their name on their certificate for completing the program or they could draw a picture with their name on it



7. FINE MOTOR

- performed during sensory motor activity

8. WARM DOWN

- cricket

9. PARENT TIME: Where to now

- reAx including GAS
- after reAx- standardised activity booklet and ~ 2 monthly contact via email

10. HEP

- Aim 1: To improve postural stability of trunk
 - ball throwing into high bucket
 - jump rope (helicopter game) - jump with both feet at same time

- Aim 2: To improve ability to weight shift and to improve co-ordination of lower limbs
 - hopping/jumping games eg. hopscotch, stepping stones
 - ball games - stand on 1 leg & move a ball forwards & backwards
 - stairs - practise alternate feet up & down (use footprints as guide)
 - tricycle riding
- Aim 3: To improve stability of upper trunk and shoulders
 - crab races over obstacles whilst keeping beanbag on tummy
 - army games eg. commando crawling over obstacles
- Aim 4: To improve position and sensory awareness and to improve co-ordination of upper limbs
 - drawing activity eg. writing my name (copy over name first)
 - 'copy me' elastic games
- Aim 5: To address child specific goals (GAS) and needs

MY ACTIVITY BOOKLET



MESSAGE FOR MUM/DAD

Now that I am between 4 and 5 years of age, I will start to become more independent from you and I will want to play with other children. Phew, I hear you say!



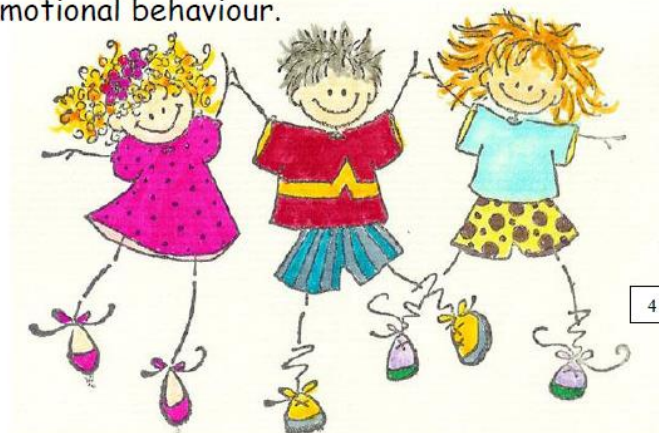
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I will try new activities and explore playground equipment.

3

Sometimes I may express my independence in rather changeable social and emotional behaviour.



4

2

PLAYING

Play Ideas:

- Imaginative play is great fun. Encourage me to dress up and make up stories with and about my toys. This will often keep me amused for 10 to 20 minutes or longer!
- Pretending to be other people like a bus driver or builder or other members of the family, is something else I like to do.
- Encourage me to tell you about what I am doing.



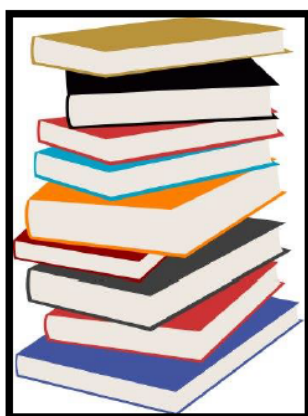
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6



7



8

READING

Books are an important part of my learning at this time. Handy hints:

- A book where I can follow through the pictures of the simple story line you are reading to me is a good way for me to develop a pattern of listening, become aware of the sequence of events as well as the meaning of the story.
- A giveaway that I am involved in the story is when you notice how eager I am to turn the page to find out what happens next!
- We could try the local library for some books I may like. I prefer those that have clear uncluttered illustrations/pictures associated with the story (picture story books). The staff may be able to help us.

3

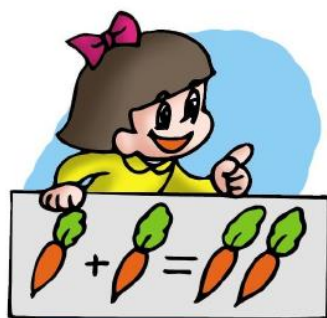
COMPARING & COUNTING

Help me find common objects around the house eg. plastic containers. I can use these objects to compare and match:

- Size - biggest/smallest.
- Shape - circle/square/triangle.
- Length - long/short.
- Height - high/low.
- Weight - heavy/light.
- Colours - blue/red/yellow.



9



I can also use these objects to practise my counting. To give me the idea, help me count the first couple of times. Lets try:

- Counting the objects 1,2; 1,2,3; 1,2,3,4, 5.
- Then with 2 objects take one away - ask me how many are left?
- Then with 3 objects take one away and ask me how many are left?

10

HAND PLAY & MUSIC

Some quiet in house activities that are fun are hand play and music activities. These include:

- Finger painting (I love to make a mess!) and playdough - these can both be home made.
- Threading large holed spaghetti onto a shoe lace to make a bracelet.
- Moving or marching to music.
- Singing and doing action songs.



11

4



DRAWING



12

Drawing with a crayon/felt pen/pencil is something I should enjoy.

A little technical, but it is important that:

- I rest my little finger side of my hand on the table/paper.
- My drawing tool is held with the pointy end between my thumb and my first two fingers.
- The stem is pointing back through the gap between the base of my thumb and my first finger.
- I have a big piece of paper.

I may tell you a story about my drawing. The drawing or the story may make no sense to you, but it is the development of my imagination that is important.

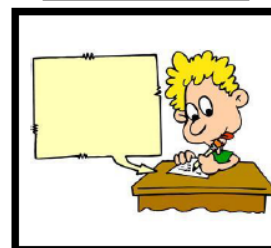
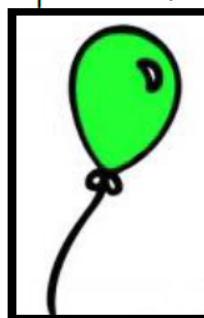
Drawing more formal shapes can also be fun such as:

- Drawing a circle - by adding a string I could make it into a balloon or by adding dots and strokes I could make it into a face.
- Drawing a square - I could change it into a kite by adding a string or a flag by adding a stick.

Another one to try is writing my name:

- First let me copy over my name.
- Next, encourage me to draw by myself the first letter of my name then add the other letters so I can recognise my name.
- I may write some letters the wrong way (or backwards) . . . oops!

We could purchase an appropriate level activity book from the local newsagent.



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LETS GET PHYSICAL

Kids my age love to be active through:

- Running, jumping and climbing.
- Going to the playground and sliding down the slippery slide, walking along a wobbly walkway or bridge and jumping over or off a step.



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At home in the garden:

- A stepping stones path can test my balance as I step from one paver to the next.
- How about I try standing on one leg?
- I may enjoy kicking, throwing and catching balls.
- Lets try riding a trike or trying to scoot a scooter too.



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NOW LETS GO & PLAY!

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APPENDIX 4: Gender effect on study participants for CBCL scores (n=50)

CBCL score	Male (n=26) Mean (SD)	Female (n=24) Mean (SD)	Test statistic	<i>p value</i>
Emotionally reactive	3.2 (2.3)	1.9 (2.3)	$F_{(1,44)} = 3.4$	0.070
Anxious/depressed	2.7 (1.8)	2.2 (1.8)	$F_{(1,44)} = 1.2$	0.289
Somatic complaints	2.5 (2.0)	1.9 (2.3)	$F_{(1,44)} = 1.2$	0.282
Withdrawn	2.6 (2.4)	1.4 (1.7)	$F_{(1,44)} = 4.1$	0.050
Sleep problems	4.2 (3.5)	2.3 (1.9)	$F_{(1,44)} = 5.0$	0.031
Attention problems	3.6 (2.6)	2.5 (2.2)	$F_{(1,44)} = 2.6$	0.112
Aggressive behaviour	10.4 (7.3)	7.1 (7.7)	$F_{(1,44)} = 2.2$	0.146
Internalizing T score	54.1 (9.7)	47.2 (10.8)	$F_{(1,44)} = 5.2$	0.028
Externalizing T score	51.4 (11.5)	44.9 (11.7)	$F_{(1,44)} = 3.6$	0.064
Total problem T score	53.3 (9.938)	45.3 (11.1)	$F_{(1,44)} = 6.7$	0.013